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ENVIRONMENTAL IMPROVEMENT

(Air, Water, and Soil)

THE GRADUATE SCHOOL
U.S. DEPARTMENT OF AGRICULTURE

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ENVIRONMENTAL IMPROVEMENT

(Air, Water, and Soil)

Edited by Ralph W. Marquis

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THE GRADUATE SCHOOL
U.S. DEPARTMENT OF AGRICULTURE

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**U. S. DEPARTMENT OF AGRICULTURE
GRADUATE SCHOOL**

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PREFACE

It is late, but it is not too late to stop the heedless and sometimes selfish pollution of our environment. It is not too late to start restoring the natural beauty and purity of the air, the water, and the soil, that so strongly affect the activities and well-being of men. There still is time to take prompt and strong action to reverse the trend toward pollution of environment.

Ever since man began to chop and dig and burn he has been remaking his environment. For thousands of years this did not seem to make much difference. There was plenty of space and not very many people.

But in recent years the explosive increase in population, combined with man's newly acquired technological ability to create and destroy, is producing effects that are not only unpleasant but may be so harmful as to threaten our very survival.

Men of many different disciplines have taken part in this lecture series on Environmental Improvement. This is important in the discussion stage if we are to gain a real understanding of the many interrelations of environmental deterioration. It will be even more important in the action stage. We have learned that whatever we do that affects one aspect of our surroundings, the action—whether good or bad—produces side effects that influence other aspects.

Planning environmental improvement must be very broad in its approach. It must be done within the constraints imposed by our institutions of Government, our appraisal of costs and benefits, and our scientific technology. And it must be done wisely if the generations to follow are to have a decent place in which to live.

We think that the Department of Agriculture's Greenspan idea as part of the Cropland Adjustment Program represents such planning for the future. In this context, I'd like to repeat a statement I made in announcing the idea in March of this year:

Man now has the power to make tremendous changes in his environment—for better or for worse. Such changes *are* being made and *will* be made—for better or for worse. Those of us who are in public life at this time have an urgent responsibility to see that these changes are for the better. Because such changes, once carved upon earth and sky, may stand for centuries.

ORVILLE L. FREEMAN
Secretary of the
U. S. Department of Agriculture

INTRODUCTION

Since 1921, the Graduate School of the U. S. Department of Agriculture has provided the Federal employees and other qualified members of the Washington, D. C., community with a continuing and varied program in adult education. As a service to the community and as one of its creative activities, the Graduate School also sponsors public lecture series such as "Environmental Improvement," which was given in the Thomas Jefferson Memorial Auditorium, U. S. Department of Agriculture, in May 1966; this book contains the texts of the lectures that were presented.

We wish to extend our thanks to all those who have contributed to the plans for the "Environmental Improvement" lecture series, and especially to the following members of our lecture planning committee: John A. Baker (Chairman), Assistant Secretary for Rural Development and Conservation, USDA; Theodore C. Byerly, Administrator, Cooperative State Research Service, USDA; John T. Barnhill, Deputy Commissioner, Federal Water Pollution Control Administration, Department of the Interior; John Coleman, Executive Officer, National Academy of Sciences; Donald E. Nicoll, Administrative Assistant to Senator Edmund S. Muskie; James M. Quigley, Commissioner, Federal Water Pollution Control Administration, Department of the Interior; Roland R. Renne, Director, Office of Water Resources Research, Department of the Interior; Harry A. Steele, Staff Economists Group, Agricultural Economics, USDA; James Sundquist, Division of Governmental Studies, Brookings Institution.

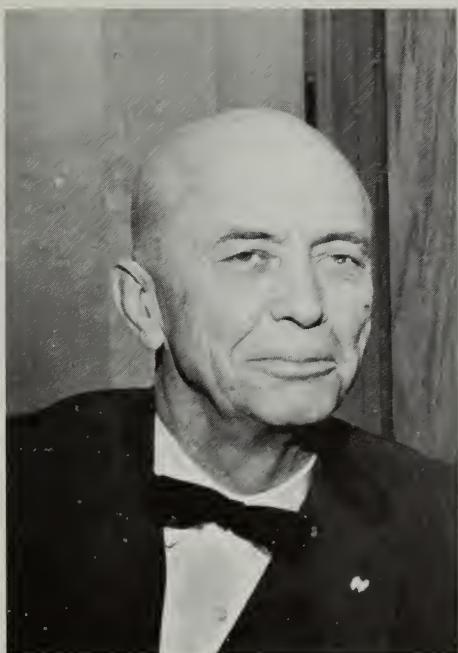
Our special thanks also go to two men in the Forest Service for the time and energy they devoted to making this publication a success. Ralph W. Marquis, Special Assistant, was responsible for the complete editing of this publication. Rudolph Wendelin, who reviews and supervises all art work using Smokey the Bear, designed the lecture symbol which appears on the cover of this book.

JOHN B. HOLDEN
Director, Graduate School



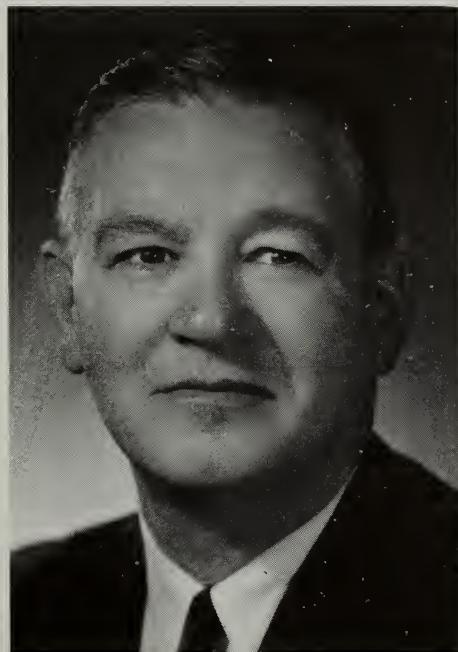
RENÉ JULES DUBOS

Professor of the Rockefeller University in New York City and has been associated with its faculty since 1927. From 1924-1927 he served as Research Assistant and Instructor in Bacteriology at Rutgers University. He was awarded the Ph.D. degree by Rutgers University in 1927. It was in 1924 that he came to the United States from his native France. He became an American citizen in 1938. Dr. Dubos is a microbiologist and experimental pathologist. Among his many scientific contributions was the first demonstration of the feasibility of obtaining germ-fighting drugs from microbes. He has received many awards and honorary degrees for his scientific achievements. He is also well known as an author and lecturer. His most recent books, published in 1965, are *Health and Disease* and *Man Adapting*.



THEODORE C. BYERLY

Administrator, Cooperative State Research Service, U. S. Department of Agriculture. He has been with the Department in a number of positions since 1929 with the exception of the period 1937-1941 when he taught at the University of Maryland. He has also taught at the University of Michigan and at Hunter College. He holds a Ph.D. Degree in experimental embryology from Iowa State University. He has received the Borden Award (1943) and Distinguished Service Award from the Department of Agriculture.



LEONARD B. DWORSKY

Director of the Cornell University Water Resources Center and Professor of Civil Engineering. With the Public Health Service from 1946-1964, and retired as Assistant to the Chief of the Federal Water Pollution Control Program. He is a graduate of the University of Michigan in civil engineering, holds a Master's Degree in Public Administration from American University, and has done advanced graduate work in water resources conservation at the University of Michigan. He is a member of the Executive Board of the Universities Council on Water Resources.

MAN AND HIS ENVIRONMENT

Scope, Impact, and Nature

INTRODUCTION: John A. Baker¹

I welcome you to the first of a series of four lectures on environmental improvement.

The key to this series of lectures is man. He is the central figure of our consideration. You will note he is the central figure on the design created to symbolize the series. We will be concerned with what man is doing to change his environment. We will be concerned with what his changed environment is doing to man. And we will be especially concerned with what man can and must do to reduce the harmful effects of his present activities and to correct the harmful situation created by past activities.

The relation of man to his environment is nothing new. He has always influenced it and been influenced by it. The increasing attention being paid to this relation in recent years can be attributed to three main causes.

The first is the explosive increase in the number of people occupying a limited space. We all have more and closer neighbors than we used to have. All of us are constantly doing something, good or bad, to influence our surroundings.

A second cause of current awareness of the problem is that the cumulative effect of all our past actions is becoming so great we

¹ Assistant Secretary, U. S. Department of Agriculture.

can no longer ignore it. We have to be aware of water and air pollution, of ugliness of man-created conditions, and the loss of natural beauty.

And a third cause is a realization that with man's astounding progress in science and technology, he has acquired the means to effect many far-reaching changes in our environment that were not even dreamed of 20 or 40 years ago—and to effect these changes in a relatively short time.

As a corollary of this third cause is the realization that man, with his scientific and technological advances, has acquired the capacity to manage his environment and is suddenly starting to do so.

You will notice from the program that this series of lectures has not been built around a group of separate measures, such as stream pollution, strip mining, highway signs, or automobile graveyards. Activities to improve our environment may have to be carried out through individual measures, but planning these measures cannot be done on an individual project basis.

Another thing we are learning is that every time something is done to improve our environment in one direction there is a very real danger that side effects may have a harmful influence in another direction. For example, weather modification to increase precipitation may be desirable to bring about an increased production of forage, crops, and timber. The danger is that natural communities may be disrupted, with a corresponding increase in pests, weeds, and pathogens. There are many reputable biologists and ecologists who hope that weather modification will not go beyond the experimental stage—or at least not until we know what the total results would be.

Our program today is concerned, not with what we could or should do to improve our surroundings—this will come in later lectures—but with those closely entangled relationships between man and his environment that create the situation in which we are living today.

SPEAKER: René Jules Dubos

Air, Water, and Earth

The three words, air, water, and soil, that define the subject matter of this symposium evoke some of the deepest, most ancient, and most lasting emotions of mankind. They symbolize also some of the greatest adventures of the human mind. All primitive people regard air, water, and earth as the very essence of material creation. The early philosophers tried to account for the structure of the universe and of the human body in terms of these primeval principles. Modern man, as we shall see, still regards them as eternal, fundamental, and essentially irreducible values.

In the 5th century B.C. the Greek philosopher Empedocles of Agrigentum wrote a didactic poem entitled "On Nature," in which he asserted that the whole world was made up of four elementary principles: air, water, earth, and fire. According to him and to the Pythagorean school, these elements were indestructible and accounted for everything that ever was, that is now, and that is to be, including man's body. In his dialogue "Timaeus," Plato applied the same view to medicine. He expounded the doctrine that health requires harmony among these four principles, and that disharmony among them inevitably results in disease. Interestingly enough, a similar doctrine was presented in a classical Chinese anthology entitled "The Golden Mirror of Medicine," published on order of the Emperor Kien Lung.

It may seem farfetched and pretentious to begin a discussion of the environment in the modern world with a reference to such antiquated Greek and Chinese theories. Crude as they are, however, these theories express attitudes and preoccupations having direct relevance to our own lives.

It has long been known, of course, that air, water, and earth are not elementary principles; they constitute immensely complex mixtures which differ profoundly from one place to the other. But despite this knowledge, the words themselves are still associ-

ated in the mind of modern man with sensations and physiological effects very similar to those experienced by ancient man. Whereas the scientist deals with air, water, and earth as crude mixtures to be studied analytically, the layman (and the scientist also is a layman emotionally) identifies the words with fundamental values of Nature to which he reacts holistically, with his whole physical and emotional being. These ancient and unchanging aspects of man's relation to nature still constitute essential determinants of his health and happiness.

Throughout ages, and in all climes, man has expressed a reverence for nature and acknowledged his dependence on air, water, and earth, by personalizing them as deities. We still worship Nature, but with a sense of guilt. The very existence of this series of lectures symbolizes a deep collective concern for the fact that industrial and urban civilization threatens to destroy the natural values that have been identified for so long with the richest emotions of mankind. One of the most painful dilemmas of our times is that we still regard nature as the ultimate source of beauty and other fundamental blessings, yet exploit and despoil it for the sake of wealth and power. We place in the parts of it that are not yet economically useful the highest qualities of nature and its beauty, but paradoxically accept the belief that economic profits justify the creation of ugliness. The sense of guilt comes from the knowledge that it is crudely hypocritical to praise the values of the wilderness, while converting the land into a gigantic dump.

To improve the environment has now become national policy, but it is not easy to formulate a philosophical basis for this policy. The word environment is so vague as to be almost meaningless, and furthermore any environmental change can affect human life in many different ways. At the cost of much oversimplification and arbitrariness, I shall attempt to highlight the complexities of the problem by making some general statements concerning the multifarious effects that air, water, and earth exert on the activities and well-being of man.

Unquestionably, most of the environmental problems in the modern world have their origin in the rapid increase of world population. Population problems are of paramount importance not only in the underdeveloped areas of the world but in the affluent countries as well, and even more. The abundance of food and of manufactured goods made available in our communities by technological achievements should not blind us to the fact that *we* are *already* overcrowded. The phrase "improvement of the environment" really denotes at the present time the hope that it is possible to minimize the further degradations of the environment that are likely to be caused by increasing population densities. It is still questionable that this conservative, and almost negative attitude, can ever be converted into a more positive policy.

All civilizations so far have been built on an orderly system of relationships linking man to nature, but these relations are being disrupted all over the world by technological forces and high population densities. Increasingly, we destroy forests and we flood deserts to create more farmland, factories, houses, and roads. We eliminate all forms of wildlife that compete with us for space and for food. We tolerate animals, plants, and landscapes only to the extent that they serve economic purposes. Highways, factories, and dwellings occupy more and more of the land areas; the use of all natural resources, including water, will soon have to be restricted to utilitarian ends. Disruption of the water cycle is speeding water on its way to the sea and increasing its destructive action on land surfaces. The denudation of the soil is creating dust bowls. Pollution of the air and of water is beginning to upset the biological balance and to damage human health. Man is rapidly destroying all the aspects of the environment under which he evolved as a species, and that have created his biological being.

Modern science is so inventive that it will probably succeed in providing mankind with technologies to compensate for the destruction of natural resources. But this alone will not correct the damage to the environment done by overpopulation and undisciplined technology. Nor will it prevent the damage to physical

and mental health caused by rapid environmental changes. Suffice it to mention here that most types of disease are the expressions of man's failure to adapt to his environment, and that adaptation will become increasingly difficult as air, water, and soil are altered more and more rapidly by the new ways of life.

The disturbances in the system of relationship between man and nature are so obvious that they are now creating all over the Western World—and especially in the U. S.—a vague nostalgia for the conditions of the pre-industrial era. This nostalgia takes different forms, depending upon the temperament and past experience of the person involved. The various aspects of it reflect the multiple views that human beings hold of nature.

For most Europeans, nature means beautiful meadows, disciplined forests, daintily tilled farmlands, streams with polished banks, manicured parks and gardens. Such humanized types of landscape also contribute to the nature scene in this country. But the more common and deeper nostalgia in the American mind is for another type of scenery, wilder and on a much grander scale than that associated with the word nature in the European mind. Words like the Rockies, the Far West, and even the Appalachians still give to the concept of nature a peculiarly American quality.

The sense of collective guilt in the U. S. comes in large part from the awareness that the immense and romantically exciting grandeur of the primeval wilderness is rapidly giving way to an immense ugliness. Brush is overgrowing mountain slopes that were once covered with majestic forests; industrial sewers are sterilizing streams that used to teem with game fish; air pollutants generate opaque and irritating smogs that dull even the most brilliant and dramatic skies. The price of the power symbolized by superhighways and giant factories is a desecration of all aspects of nature.

The waste of natural resources, the threats to health, the annihilation of civilized sceneries, and the destruction of the wilderness all constitute as many different aspects of the environmental prob-

lem in the modern world, each with characteristics of its own. But irrespective of their differences, all cause conflicts with some traits that have been woven into man's very fabric during his evolutionary development. Man evolved in association with natural forces, and civilized as he may be the natural world is still essential to his well-being.

For lack of hard, empirical reflection on the subject, it is difficult to harness evolutionary metaphysics to the practical problems of the modern environment. Scientists, like moralists, react to environmental problems with deep and many-sided sensibility and insight, but they have not so far contributed much precise knowledge to their solution. It may be of some help nevertheless to consider the human aspects of the environment from the point of view of evolutionary history. To this end, I shall take in succession two different points of view that reveal two complementary pictures of human needs. One shows that man's fundamental nature and his responses to the environment have not changed significantly since the Stone Age. The other confirms the obvious truth that since human societies are constantly changing, they must endlessly transform the environment in which they function.

Nature and the Unchangeable Aspects of *Homo Sapiens*

Surprising as it may seem, *Homo sapiens* has remained essentially the same since he became differentiated as a distinct biological species late in paleolithic times, some 50,000 years ago. All biological characteristics and needs of modern man, as well as his susceptibilities and mental reactions, are governed by the assembly of genes that governed the life of ancient man when he was a paleolithic hunter or a neolithic farmer. The ways of life have changed, of course, but physiologically and emotionally the fundamental requirements of mankind are still today what they have always been. Ancient art is profoundly meaningful to us and indeed appears timeless precisely because it resonates with the many aspects of man's nature that are unchangeable.

The permanency of man's nature imposes a fundamental pattern on the philosophy of environmental improvement. This philosophy cannot be formulated in the abstract. To be good for man, the environment must be compatible with the unchangeable needs of his nature. There is no doubt, of course, that like other biological species, *Homo sapiens* can undergo genetic changes enabling him to adapt to new conditions. But biological (genetic) evolution is far too slow to permit effective adaptation to the rapid changes that commonly occur in the physical environment at the present time. Fortunately there are certain physiological and psychosocial adjustments that can be made without changing the genetic endowment. These adjustments are often stressful and result in disease, but at least they enable man to survive and to function in environments that are potentially deleterious.

A century ago, especially under the influence of Lamarck and of the popular science inspired by Herbert Spencer, it was believed that the habits and tolerance engendered by exposure to a new environment were handed on to succeeding generations by biological inheritance, but this belief was erroneous. Many of the so-called "acquired characteristics" are culturally transmitted by the learning process, but most of them are not genetically inherited. Biologically, each generation starts in all essentials not from where its fathers left off, but from where they began.

There are limits furthermore, to the range of adaptation that man can achieve through acquired characteristics. In other words, it is unjustified to hope that man will eventually be able to adjust biologically to all the new conditions created by crowding and technological developments. The frontiers of the environmental changes that man can tolerate will be determined by the frontiers of his adaptive potentialities.

There is widespread awareness that almost any excessive level of pollution of air, water, and soil will have deleterious effects on man because his evolutionary past has not prepared him to cope with modern pollutants. But it is less commonly realized that

quality and quantity of emotional stimuli are important in this regard. For lack of precise knowledge concerning such aspects of man's evolutionary nature, two analogies derived from the animal kingdom may help in visualizing the nature of the problem.

Even though the dog has been domesticated since the neolithic period, it still retains many of the behavioral characteristics of the wild species from which it was derived. Likewise, the cat still has a "need" to hunt, even when pampered and well fed in a city apartment. Civilized dog and civilized cat are outwardly very different from their primitive ancestors, but their essential dogness and catness have survived under the veneer of civilization.

In man, also, there persists certain deeply ingrained psychological needs that have as much force as orthodox physiological requirements. The pathetic exodus to the "country" every weekend and whenever conditions permit obviously means more than the mere search for comfort and quiet. It is an expression of man's biological urge to maintain contact with the kind of environment in which he evolved. There is profound biological truth in the words of Paul the Apostle: "Man is of the earth, earthy." Granted that it is part of man's nature to make him behave at times like a Lucifer, more commonly like a Faust, and now and then like an angel, the fact is that biological man cannot remain healthy very long if he loses all contact with his earthy origins. The ancient Greeks symbolized this truth in the legend of Anteus who lost all his strength as soon as his two feet were simultaneously off the ground.

The knowledge of man's origins is admittedly very incomplete, but it is sufficient nevertheless to leave no doubt that his genetic evolution came almost to a standstill many thousands of years ago. Certain qualities of the environment are essential to his well-being and indeed his survival because he developed in association with them during his evolutionary past and acquired a dependence on them that he can hardly outgrow through genetic changes. In this light, the word recreation becomes much more meaningful

when spelled re-creation. For reasons difficult to define scientifically, but nonetheless imperative, man needs now and then, and perhaps often, to reestablish direct contact with the natural environment in order to recover his physiological vitality and psychological sanity.

The Adaptability of Mankind and the Dangers of Adaptation

While the fundamental genetic traits of the species *Homo sapiens* are permanent and universal, it is obvious that the ways of life of human societies are constantly changing. They differ not only with time but from one area to the other because mankind is endowed with a wide range of adaptive potentialities. Through biological and social mechanisms of adaptation that are largely independent of genetic evolution, human beings have been able to establish themselves all over the earth. They can even survive, function, and multiply in environments that appear at first sight almost incompatible with life.

The experience of the historical period suggests that man has remained as adaptable as he was in the ancient past. The rapid increase in population during the 19th century occurred even though the proletariat was then living under conditions that most of us would find almost unbearable. In our own times, human beings are achieving some form of physiological and socio-cultural adjustment to the many forms of stress which they experience in industrial and urban environments. Many of them have managed to function in concentration camps and to survive the frightful ordeal of combat during the war!

Modern man is adapting to environmental pollution, to intense crowding, to deficient or excessively abundant diets, to monotonous, ugly and depressing environments. All over the world, the most polluted, crowded, and traumatic cities are also the ones that have the greatest appeal and where population is increasing most rapidly. Furthermore, conditions that appear undesirable biologi-

cally do not necessarily constitute a handicap for economic growth. Great wealth is being produced by men working under high nervous tension in atmospheres contaminated with chemical fumes, or in crowded offices polluted with tobacco smoke.

Biologically speaking, adaptability is almost by definition an asset for survival. However, the very fact that man readily achieves some form of biological or social adjustment to many different forms of stress is paradoxically becoming a source of danger for his welfare and his future. The danger comes from the fact that this adjustment commonly results in pathological consequences; but these pathological effects are often delayed, and extremely indirect. Consequently it is usually very difficult to relate the damage caused by the environmental insults to its primary cause. Atmospheric pollution in the industrial areas of Northern Europe strikingly illustrates the distant dangers of human adaptability.

Ever since the beginning of the Industrial Revolution, the inhabitants of Northern Europe have been heavily exposed to many types of air pollutants produced by incomplete combustion of coal, and released in the fumes of chemical plants. Such exposure is rendered even more objectionable by the inclemency of the Atlantic climate. However, long experience with pollution and with bad weather has resulted in physiological reactions and in living habits that have adaptive values. This is proved by the fact that Northern Europeans accept almost cheerfully their dismal environment even though it appears almost unbearable to outsiders who experience it for the first time. Adaptive responses to environmental pollution are not peculiar to Northern Europeans. They occur all over the world in the heavily industrialized areas whose inhabitants function effectively despite constant exposure to irritating substances in the air they breathe. It would seem therefore that human beings can readily make an adequate adjustment to massive air pollution. In fact, Gerard Piel recently wrote in *The Bulletin of the New York Academy of Medicine* that there is "no

clear connection . . . established between air pollution and health. Abel Wolman, the senior member of the current generation of municipal sanitation engineers, thinks it is principally an esthetic affliction. Wolman observes: 'If exhaust gases emitted by a Diesel bus had a fragrant aroma or, worse yet, led to physiological addiction, not many people would complain about traffic fumes.' "

Air pollution unfortunately is not only an esthetic affliction. Its acceptance results eventually in various forms of physiological suffering and economic loss. Even among persons who seem almost unaware of the fumes and smogs surrounding them, the respiratory tract continuously registers the insult of the various pollutants. The cumulative effects of such exposure commonly become manifest in the form of chronic bronchitis and other pulmonary diseases later in life.

Chronic pulmonary disease now constitutes the greatest single medical problem in Northern Europe, as well as the most costly, and it is becoming increasingly prevalent also in North America. There is good evidence, furthermore, that air pollution also increases the numbers of fatalities among persons suffering from vascular diseases as well as the incidence of various types of cancers. But the long and indefinite span of time that usually separates cause and effect makes it difficult to relate the manifestations of the pathological conditions to the primary physiological insults. It is for this reason, and for this reason only, that so far, "no clear connection has been established between air pollution and health."

One can almost take it for granted that unless social attitudes change, society will become adjusted to the levels of air pollution that do not have gross immediate nuisance value—even though this apparent adaptation will eventually result in much pathological damage and many social burdens. A similar situation will probably develop with regard to other aspects of the environmental pollution problem such as concern water.

Highly effective techniques have been developed to control the acute diseases that used to be caused by the microbial contamination of water. Microbial pathogens can be held in check by chlor-

ination; organic matter content can be minimized by dilution, oxygenation, and other chemical techniques; and water can be made limpid by filtration. But there are no practical techniques for removing the inorganic materials and the various synthetic organic substances that tend to accumulate in water supplies as a result of industrial and domestic usage. Even though clear and free of pathogens, many sources of potable water now contain a variety of chemical substances that may have delayed toxic effects. This constitutes a new kind of threat to health which, though ill-defined, bids fair to become of increasing importance in the near future.

Allowing that the dangers created by modern technologies and environmental changes have been exaggerated, there are many facts which nevertheless justify anxiety for the future. One of the alarming aspects of environmental pollution is that despite all the new powers of science, or rather because of them, man is rapidly losing control over his environment. He introduces new forces at such a rapid rate and on such a wide scale that the effects are upon him before he has a chance to evaluate their consequences and can afford to change his course. For example, the photochemical conversion of hydrocarbons and of nitrous oxides into the toxic products responsible for the Los Angeles type of smog was recognized only after the California economy had become dependent on an excessive concentration of automobiles and industries. The absorption of radioisotopes in the human body became known only several years after the beginning of large scale nuclear testing. The resistance of synthetic detergents to bacterial decomposition began to cause trouble only after their universal use as household items had led to their accumulation in water supplies.

The dangers posed by environmental pollutants are rendered even more difficult to evaluate and to predict by the fact that these substances usually have indirect effects which manifest themselves through a complex chain of reactions. Most biologically active substances act indirectly through other members of the ecological system to which the organism belongs. For example, one of the

unexpected findings to emerge from the Chariot project was that lichens have an extraordinary power to concentrate Strontium 90 from fallout. As lichens constitute the main source of food for reindeer, and as these animals in turn constitute an important food for Eskimos and other residents of the Arctic regions, it is obvious that the selective uptake of Strontium 90 by lichens greatly magnifies the hazards of fallout for human beings in the Arctic.

The preceding examples illustrate that immensely complex studies will be required to bring to light the pathological effects created on man by environmental pollutants and other biologically active substances. These studies will have to deal not only with immediate primary effects, but also with secondary effects involving structures and functions other than those primarily affected. Man is part of a complex ecosystem which responds as an integrated whole to each of the forces making up the total environment.

Needless to say, exposure to toxic agents is not a new experience for mankind. It became prevalent as soon as man escaped from the restraints of organic evolution and began civilized life. However, the problems posed by environmental stimuli and insults have acquired a critical urgency. In the past the rate of change was generally so slow that mankind, if not individual persons, could unconsciously make the adjustments necessary for survival. The genetic character of the population became progressively altered; phenotypic modifications helped many individuals to function effectively in their ecological niche; and especially, man learned to achieve better fitness to his milieu through technological and social innovations. In contrast, the rate of technological and social change is now so rapid that it affects almost simultaneously all parts of the world and all economic classes. There is no longer enough time for the orderly and successful operation of the unconscious adaptive processes that were the salvation of mankind in the past. Biologically and socially, the experience of the father is becoming almost useless to the son.

Nature as Human Creation

Many persons are becoming weary and frazzled by the rat race of constant change. Their cry goes up: "Stop the world. I want to get off." They urge that we go back to Arcadia, and live once more in the simple purity of Nature. But Arcadia has never existed except in dreams.

Throughout the ages, true enough, it has been widely believed that mankind could enjoy health and happiness by living in accordance with the ways of nature. This romantic ideal, however, is incompatible with the human condition. Man abandoned the ways of nature in the very process of becoming human, when he began to modify his environment by using fire, cutting down forests, tilling the land, opening roads, covering himself with clothing, building houses for shelter, etc. In fact, the word "nature" does not denote a definable and constant entity when applied to human life. There is not one *nature*; there are combinations of states and circumstances associated with the different ways of life.

Although man can exist only within an extremely narrow range of conditions determined by physiological exigencies, he has learned to manipulate the external world so as to render "natural" many kinds of environments exhibiting an astonishingly wide range of moods. Indeed the word nature means very different things to different men. It is a far cry, for example, from the equatorial jungles to the Great Barrens, from the Sahara Desert to the fogs of Newfoundland, from the depths of Arizona canyons to the high altitudes in the Peruvian Andes. Yet man has managed to live and sustain civilization in all these different places, all of them constituting an equal number of different types of nature. It could almost be said that there is no such thing as "nature" for man; there are only homes. For a particular person, almost everything is "unnatural" outside the home environment to which he has become adapted.

Adaptation, however, does not mean a static equilibrium between man and his environment. The ancient Greek concept of harmonious equilibrium with nature has a Platonic beauty, but it lacks the flesh and blood of real life. It fails to convey the creative quality of human existence.

Homo sapiens probably achieved his biological identity on the shores of some inland sea with a mild climate, but he has moved far from the place of his generic birth in the course of his countless adventures. For thousands of years the "nature" to which he had to adapt included the various climates and soils, plants and beasts, periods of plenty and of famine, and all other factors of his total environment, with which he came into contact and experienced during his long evolutionary journey. For modern man, the word "nature" must now include his urban and industrial creations.

The human saga has been the endless search for new environments; and each new move has required adaptive changes often painful and dangerous. The need for continuous adaptation with all the threats that it implies would disappear only if men could remain stable in a static environment. But in the world of real life men constantly change their ways, and places also change. The solution to environmental problems cannot be found, therefore, in a return to an imaginary Arcadia or in the search for a static Utopia. As man continues to modify nature and to create new civilizations, unexpected dangers will continuously arise. The most man can do is on the one hand to make sure that the environmental changes he brings about do not outstrip his adaptive potentialities, and furthermore to govern his adaptive responses in such a manner that they do not decrease the qualities of his life.

The present series of lectures is focused on air, water, and soil because of the general awareness that these essential environmental factors are most acutely threatened by modern civilization. But while the specific problems are fairly obvious, it is much more difficult to define the meaning of the phrase "improvement of the environment." The difficulty is that quality involves taste and

perception, and where these are concerned, individual factors intervene that make consensus all but impossible. Walden Pond as a public bathing and boating place may serve the needs of a public park, but would have no appeal for Thoreau.

Allowing for all the individual differences with regard to quality of the environment, there are a few problems that are not controversial and demand immediate action. The most immediate is to determine the maximum levels of contamination that can be tolerated from the health point of view. As already mentioned, toxicity must be measured not only in terms of obvious nuisance and of immediate deleterious effects, but also of delayed and indirect consequences.

Some of these indirect and delayed consequences will naturally affect physical health and will therefore be measurable objectively. But others will be concerned with more subtle qualities of human life and will require qualitative value judgments. Because man is so adaptable he can learn to tolerate murky skies, chemically treated waters, and lifeless land. In fact, he may soon forget that some of his most exhilarating experiences have come from direct contact with the freshness, brilliance, and rich variety of unspoiled natural phenomena. Unfortunately, perhaps, starless skies and joyless sceneries are not incompatible with the maintenance of life, or even with physical health. The only measure of their loss may be a progressive decadence in the quality and sanity of the human condition.

It may be difficult to justify economically the cost of maintaining the esthetic quality of the natural environment. The best that can be said on this score is to echo Oscar Wilde's scorn for those who know the price of everything and the value of nothing.

The most important values, unfortunately, are not definable in forms of any specific qualities or characteristics of nature. They involve man's relation to his total environment. The subtle complexity of this relationship has been poetically formulated by the English scientist and writer Jacquetta Hawkes in her book *A Land*. She expressed in the following words her belief that Eng-

land had enjoyed during the 19th century a high level of harmony between the human condition and the development of the countryside:

Recalling in tranquility the slow possession of Britain by its people, I cannot resist the conclusion that the relationship reached its greatest intimacy, its most sensitive pitch, about two hundred years ago. By the middle of the eighteenth century, men had triumphed, the land was theirs, but had not yet been subjected and outraged. Wildness had been pushed back to the mountains, where now for the first time it could safely be admired. Communications were good enough to bind the country in a unity lacking since it was a Roman province, but were not yet so easy as to have destroyed locality and the natural freedom of the individual that remoteness freely gives. Rich men and poor men knew how to use the stuff of their countryside to raise comely buildings and to group them with instinctive grace. Town and country having grown up together to serve one another's needs now enjoyed a moment of balance.

Appealing as it is, the picture of 18th century England drawn by J. Hawkes cannot serve as a model for solving 20th century environmental problems and reestablishing harmonious relationships between modern man and the external world. But it provides nevertheless a useful lesson for the future.

Our social philosophy is based on the assumption that nature must be "conquered" so that it can be exploited more effectively. However, conquest, or mastery, is not the only nor the best manner to deal with natural forces. Man should try instead to collaborate with them. Ideally, he should insert himself into the environment in such a manner that his ways of life and technologies make him once more part of nature.

Modern ecological studies leave no doubt that almost any disturbances of natural conditions are likely to have a large variety of indirect unfavorable effects because all components of nature

are interrelated and interdependent. The different living forms are organized into a highly integrated web which is only as strong as the weakest of its constituent parts. Moreover this web is supported by the physical environment.

Man needs other human beings and must maintain harmonious relationships with the land; he is also indirectly dependent on other creatures—animals, plants, and microbes—with which he evolved and that form part of the integrated patterns of Nature. Unquestionably, he will destroy himself if he thoughtlessly and violently upsets the complex and delicate web of life of which he is a part. It is the interdependence of all living things, and their complex relation to the physical environment, that constitutes the scientific basis of conservation policies.

Conservation means much more than providing amusement grounds and comfortable camps for weekenders. Its ultimate goal should be to help man retain contact with the natural forces under which he evolved and to which he remains linked physiologically and emotionally. Like Anteus of Greek mythology, as already mentioned, man loses his strength when his two feet are off the earth.

Physical and mental well-being here and now are not, however, the only determinants of sanity and happiness. Man is not isolated in time; he needs to relate to the past and the future. In this light, we should give thought to what our own civilization will leave for the generations to come. Where are the monuments of today that will survive two thousand years hence? Where are the gardens, parks, and avenues of trees made of lasting species and planted in a noble style, that could become increasingly poetical and majestic with added centuries? Improving the environment should be a creative collaboration between man and nature.

Only two kinds of landscape are fully satisfying. One is primeval nature undisturbed by man; we shall have less and less of it as the world population increases. The other is one in which man has toiled and created through trial and error a kind of harmony

between himself and the physical environment. What we long for is rarely nature in the raw; more often it is an atmosphere suited to human limitations, and determined by emotional aspirations engendered during centuries of civilized life. The charm of the New England or Pennsylvania Dutch countryside should not be taken for granted, as a product of chance. It did not result from man's conquest of nature. Rather it is the expression of a subtle process through which the natural environment was humanized, yet retained its own individual genius.

Air, water, soil—these simple words convey much more than material aspects of nature. They symbolize some of the deepest needs of human life because man is still of the earth, earthy.

Environmental planning has become necessary because man cannot be safely dissociated from the natural forces under which he evolved and that have molded his own unchangeable biological nature. Fortunately, the success of certain highly organized states like Sweden indicates that large scale and environmental planning is possible. The possibility to plan toward esthetic qualities is even more convincing. One needs only evoke the marvelous parks of Europe to realize the usefulness of a long range view in social improvements.

These parks were the creations of artists who had visualized the outcome of their efforts with that extraordinary sense which is peculiar to man, the imaginary vision of things to come. Several books by the great landscape architects of the 18th century show drawings of the European parks as they appeared at the time of their creation, and then a century later when the plantations had reached maturity. It is obvious that the landscape architects had composed the surfaces of water, of lawns and flowers to fit the silhouettes of trees and the masses of shrubbery not as they existed at the time, but as they were to become. And because men could thus visualize the future and plan for it centuries ago, millions of human beings enjoy today the great European parks and classical gardens.

In general, the phrase "social planning" evokes the thought of Utopias—conceived in terms of rigid social institutions. Such utopias are now out of fashion, in part as a result of the progressive erosion of the belief in rational progress and more justifiably because of the general awareness that static institutions are not viable. The regrettable consequence, however, is that 20th century intellectuals are now inclined to caricature the world and to replace utopias by anti-utopias. Yet, utopian thinking presents a great intellectual challenge. To formulate alternatives for the present state of affairs is more difficult than simply to protest against evils.

An immense amount of money and effort will certainly be expended in the years to come on programs of environmental control. It is therefore essential that we try, collectively, to imagine the world in which we want to live. The great periods of history have always created such ideal images through their social philosophers and their artists.

Improving the environment should not mean only correcting pollution or the other evils of technological and urban growth. It should be a creative process through which man and nature continue to evolve in harmony. At its highest level, civilized life is a form of exploration which helps man rediscover his unity with nature. In the words of T. S. Eliot,

We shall not cease from exploring,
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

REACTION: Leonard B. Dworsky

Dr. Dubos has drafted a magna charta for man in relation to his earthly environment. Unlike the charter of human liberties, the present draft aims to guarantee to nature a larger degree of freedom from insult at the hands of man. In so doing, man is insuring his own future, for the survival of man is linked inseparably to his environment.

We are again in debt to Dr. Dubos, during this period of national debate, for providing a view of man and environment which cuts away the underbrush and leaves the issues so revealed that all, whether in high places or low, can understand the consequences of their actions.

This paper is remarkable also for its completeness and for its courage. Few men of science would lean as heavily on "natural law" as a basis for controlling human activity. But Dr. Dubos has related philosophy, science, and the limits of man's knowledge so effectively that, in the absence of more precise means, the use of a normative heavily weighted by "natural law" to measure man's impact on nature feels right.

Dr. Dubos reiterates the role of man as a creature of nature and as a creator of change in nature. How is man to reconcile the conflicts created by these two roles? Dr. Dubos reminds us of our history and of the role of the social philosophers and the arts in creating an image of the world in which we want to live.

This paper is so concise and thoughtful that every sentence must be weighed. A number of quotes will illustrate what I mean.

"Throughout ages . . . man has expressed a reverence for nature. . . ."

"We still worship nature, but with a sense of guilt."

"To improve the environment has now become national policy, but it is not so easy to formulate a philosophical basis for this policy."

"Man evolved in association with natural forces, and civilized as he may be, the natural world is still essential to his well-being."

"Air pollution . . . is not only an esthetic affliction. It . . . results eventually in . . . physiological suffering and economic loss. But the long and indefinite span of time that usually separates cause and effect makes it difficult to relate pathological conditions to the primary physiological insults. It is for this reason, and for this reason only, that so far no clear connection has been established between air pollution and health.'"

"One can almost take it for granted that unless social attitudes change, society will become adjusted to the levels of . . . pollution that do not have gross immediate nuisance value . . . even though this apparent adaptation will eventually result in much pathological damage and social burden."

"Man is rapidly losing control over his environment. He introduces new forces at such a rapid rate that . . . the effects are upon him before he has a chance to evaluate their consequences and can afford to change his course."

"Biologically and socially, the experience of the father is becoming almost useless to the son."

"It is the interdependence of all living things and their complex relation to the physical environment that constitutes the scientific basis for conservation policies."

Among the many points covered by Dr. Dubos, three seem to me to be of special interest.

The first involves the determination of a set of normative values as a basis for measuring the importance and the effect of environmental variations. Dr. Dubos has suggested a reliance on the "natural law," but not in the mystic manner of the classical social philosophers. His "natural law" is buttressed by all the findings of the biological and physical sciences.

Thus, he notes, "The permanency of man's nature naturally imposes a fundamental pattern on the philosophy of environmental improvements. . . . To be good for man the environment must be compatible with the unchangeable needs of his nature."

He further comments that biological (genetic) evolution is far too slow to permit adaptation to the rapidly changing physical environment although some adaptation to environmental hazards can be made, but not without, ultimately, physiological and psychological stress.

Because man's knowledge is incomplete, these views have been questioned from several points of view, but most often by those squeezed by the economic consequences. While some important gains have been made toward accepting the normative values implied by Dr. Dubos (for example, we now have Senator Nelson's bill on ecological research), the relative gain compared to the rapidity of change induced by science and technology leaves little room for complacency about the tasks remaining if we are to live within the modern view of the "natural law."

Secondly, it seems to me that Dr. Dubos's paper represents a large plea for an attitude of humbleness on the part of man. To "know thyself" applies not merely to the individual, but to all mankind. The Old Testament injunction "to walk humbly" is most applicable in these days considering man's power to use elemental force, to create genetic change and, perhaps tomorrow, to change the weather. Dr. Dubos has shown us the limits of our knowledge, but he has also held up for us to see some of the consequences of our efforts. The tools of science and technology in the hands of man must not be used with godlike authority. Through humbleness, man can gain time which, in the end, may be his salvation.

For the third point, Dr. Dubos, in referring to the inability of man to evaluate the consequences of his actions in the light of rapid change joins with the scientific community in seeking a greater measure of effort by both the social and physical scientist to understand and manage the consequences of technological changes. The need for this effort has been expressed by C. P. Snow, who recently said, ". . . We are more ignorant than is wise, or safe, or human."

In stating the problem of environmental degradation, it is difficult not to view the situation with pessimism. Recent reports

by the National Academy of Sciences and The Office of Science and Technology have been generally in this vein, and properly so in my opinion. Dr. Dubos has not only stated the basic problems, somewhat along the same lines, but he also has given us the hard supporting arguments to mount a vigorous and positive offensive in favor of environmental normality.

The crux of the matter, of course, is the determination of normality. Having stated this major issue, I must leave it undeveloped here because of time (although I have stated elsewhere goals in connection with water pollution control; see The White House Conference on Natural Beauty).

However, Dr. Dubos has shown us that the induced variations from natural conditions in air and water are sufficient to cause significant health, economic, and cultural damage to man. We are also alerted to the fact that we are rapidly losing control over the environment.

It would seem, therefore, that prudent policy would dictate a reversal of this trend and move toward that kind of creative normality spoken of by Dr. Dubos as soon as possible and that we do what we can with the tools at hand.

I am developing a confidence that we are moving toward such a prudent policy in connection with the water pollution problem. Let me close my remarks by explaining this position.

In water pollution, government and public leaders have brought about an unusual public consensus in the last 15 years. In most places, people are in advance of politicians.

The Nation has good, although not complete, information about the water pollution problem. It is applying this information well in identifying the problem points and in establishing a workable control program to get accomplished what can be done now.

Dollars for construction of physical facilities are being proposed in amounts large enough to build our needed treatment works. Senator Muskie and others have bills before Congress calling for 6 billion dollars to be authorized as Federal assistance to local communities by 1972.

The ultimate decision, however, about what the Nation's water resources will be like in the future depends on how well and how soon science and technology develop new or improved waste treatment methods and at what cost. We have been completely irresponsible in this aspect of need if we contrast the one million dollar program for new waste treatment research against the national commitment of about 16 billion dollars for research and development. Legislation now proposed by Senator Muskie and others is intended to close this gap.

What we seek, and what I believe we have good hope of achieving, is a total separation of water from polluting substances. If our technology develops well, we have the possibility of having very clean rivers at our disposal in the longer future. For the short run, we may have to be satisfied with the removal of gross pollutants everywhere which will require, in the main, secondary waste treatment by cities and its equivalent by industries. The expression of this treatment requirement as a national minimum ought to be stated as a basic policy by the Congress, along with an understanding that higher cost unique treatment will also be required (and will not be jeopardized by this policy) at critical locations like Lake Tahoe, the Great Lakes, and elsewhere when needed.

I am optimistic about the future management of water pollution. Our national objectives are becoming clear—to protect and enhance water quality; our people are alert; government machinery is moving; and I am confident we have the opportunity to reverse the tide and achieve control of this phase of our environmental problem.

We can fail, however. Industry can hold back. The people might prefer to spend their dollars for personal consumption items. Government might falter. Science and technology may not meet our expectations.

It has been a privilege for me to respond to Dr. Dubos's outstanding discussion and I am indebted to the Graduate School of the Department of Agriculture for this opportunity.

REACTION: Theodore C. Byerly

Dr. Dubos has indicated little change, past or prospective in the genetic adaptation of man to the environment. I support his point of view but he knows that many do not. I wonder, though, if it will be much easier to conform the environment to man?

But there is a stir in the world. The UNESCO 1967-68 program contains an item for an intergovernmental conference on the rational use of the biosphere—air, land, and water. The International Biological Program is underway in more than 25 countries, including the United States. Its theme is the biological basis of productivity and human adaptability.

A National Academy of Sciences Committee on waste management under the chairmanship of Athelstan Spilhaus has reported. In general, the Committee viewed pollution as a problem of waste management rather than disposal, and urged that society take steps to recycle its residues back into productive use, rather than leaving them for future generations.

Man can no longer throw away his refuse, for there is no more "away," the report declares. "As the earth becomes more crowded . . . one person's trash basket is another's living space."

Gross waste is a part of the balance of nature. We are concerned with managing it to our advantage. Biologically the processes in returning grain to its elements through a rat are about the same as through a man—or indeed through molds or bacteria, for that matter.

Either way, most food becomes a recurring component in the food chain.

If we want to live; if we want a world fit for our children's children and their children, then biology offers the means to make it so. Or, alternately, the means to prevent its ever being a better place than it is now. If this, the here and now, is the best of all possible worlds, why then let's relax and enjoy it.

Within very broad limits, the biological world, and we a part of it, is a continually renewable world. Trapping energy from the sun, green plants and some bacteria use it to convert water and carbon dioxide to compounds biologically usable for energy. During the past a small, but a cumulative portion, of each season's trapped energy has been stored in the earth as humus, peat, lignite, coal, gas, and oil. During the past 100 years, we've drawn on this store of fossils at an accelerating rate. The ultimate exhaustion of our store of fossil fuel is foreseeable; inevitable. But the probable exhaustion of sun's energy seems very remote.

Man has lived on this earth for a long time; perhaps a half million years. Numbers of men increased pretty slowly for a long, long time. More recently, population has increased very rapidly, doubling in the past 50 years and likely to double again in an even shorter period.

This burgeoning population makes urgent the even greater acceleration of acquisition and application of new knowledge about man and the biological portion of the world in which we live. Of all the people who have ever lived, about 4 percent are alive now. We are consuming the resources of the earth and contaminating the earth with our residues. Most important of these is the very CO₂ necessary to the energy storage upon which our biological world principally depends. So what?

Man cultivates about 3 billion acres to support 3 billion people. It could support three times that number; but would we like it?

A statement attributed to Lao-Tse is: "A government conducted by sages would free the hearts of the people from inordinate desires, fill their bellies, keep their ambitions feeble and strengthen their bones. They would constantly keep the people without knowledge and free from desires; and, where there were those who had knowledge, they would have them so that they would not dare to put it into practice."



EDMUND S. MUSKIE

United States Senator from Maine since 1958. Member of three standing Senate Committees—Banking and Currency, Public Works, and Government Operations—and Chairman of three Subcommittees, including the Subcommittee on Air and Water Pollution. He was Governor of Maine for two terms, 1954-58. He served in the Navy in World War II and practiced law in Waterville, Maine, following the end of hostilities in 1945. He is a graduate of Bates College and obtained his legal training at Cornell Law School. He has been active in Democratic politics. Senator Muskie has sponsored much progressive legislation. He is the author of the Water Quality Act of 1965 and of the amendments to the Clean Air Act of 1963.



JOHN A. CARVER, JR.

Under Secretary of the Interior since 1965, prior to which he served 4 years as Assistant Secretary of the Interior for Public Land Management. From 1957 to 1961 he was Administrative Assistant to Senator Frank Church of Idaho. He practiced law in Boise, Idaho, from 1948 to 1957. He holds an A.B. Degree from Brigham Young University and had his legal training at Georgetown University. He is a member of the bar in Idaho and the District of Columbia and a member of the American Bar and Federal Bar Associations.



DEAN W. COSTON

Deputy Under Secretary, Department of Health, Education and Welfare. He has also served in this Department, since 1961, as Special Assistant to Assistant Secretary (Legislation) and Deputy Assistant Secretary. He has held a number of municipal and county public offices closely related to planning activities, and a number of offices in the Democratic Party. He is the author of professional articles on pollution, education, and urban affairs.

ENVIRONMENTAL IMPROVEMENT

Institutional and Governmental Aspects

INTRODUCTION: John A. Baker

Welcome to the second lecture of our series on Environmental Improvement.

Dr. René Dubos opened this series last Tuesday. He impressed us with the real dangers that deterioration of our environment presents. His discussion went beyond the esthetic aspects of our surroundings and into a consideration of biological effects. He traced man's relation to nature, and noted that genetically man has changed very little over the centuries. He can live in a new environment only because of his adaptability.

Dr. Dubos then pointed out that the very ability of man to adapt to environmental change carries a danger in itself. He can learn to tolerate pollutants in the air. But this adjustment causes him to ignore the delayed pathological effects. He cited the case of the Northern Europeans who, since the Industrial Revolution, have been exposed to many types of air pollutants. They accept their dismal environment, but chronic pulmonary disease has become the greatest single medical problem in that area.

We all have our individual parts to play in hurting or improving our immediate environment. But anything we do to make significant changes in our environment must be done within the framework of our social, economic, and legal institutions. The institutional and governmental aspects of environmental improvement is the subject of today's presentation.

SPEAKER: Edmund S. Muskie

I am pleased and honored by the opportunity to participate in this lecture series. The topic is timely. It is serious. And it affects each one of us.

Last Tuesday, Dr. Dubos set the tone and the measure for the series with his learned and penetrating examination of man's dilemma in an increasingly crowded and polluted environment. I would like to quote the following from his lecture:

"The solution to environmental problems cannot be found . . . in a return to an imaginary Arcadia or in the search for a static Utopia. As man continues to modify nature and to create new civilizations, unexpected dangers will continuously arise. The most man can do is on the one hand to make sure that the environmental changes that he brings about do not outstrip his adaptive potentialities and furthermore to govern his adaptive responses in such a manner that they do not decrease the qualities of his life."

The problems of pollution are not new. They have plagued man from the earliest civilizations. Man cannot live without creating wastes, and those wastes represent a potential threat to his health and to life itself.

But in recent years the threat has been magnified and has become, in effect, a new problem. Our population has grown to a point where our water needs are almost greater than the available supply. At the same time we have succeeded in creating chemical and radioactive wastes whose characteristics have almost defied our efforts to clean them up.

Our increasing energy needs—for manufacturing, heating and cooling, and transportation—have led us to a dangerous point in polluting the air we need to sustain life.

And in our pollution of the water and the air we have made subtle changes which threaten the very balance of man's body and mind.

Contamination of the environment is a social problem. Up to a point we can reduce the problem by individual action—by restraining the impulse to throw litter on the pavement or in the park, by keeping our cars and furnaces in good operating order, or by observing sound conservation practices on our own property. But in a society as complex as ours, where practically everything we do to maintain life and to produce goods and services results in contamination of the environment, public decisions and public actions are needed to improve the environment.

For many years we ignored this fact, particularly in times when the relationship between pollution and ill-health was not understood. There were early efforts but they were spasmodic.

George Washington, for example—who was a rather indifferent member of the Virginia House of Burgesses—introduced legislation to regulate the keeping of swine so as to protect wells from contamination.

The gap between that pre-revolutionary gesture toward clean water and the first substantial water pollution control efforts was over 100 years. Serious attention to air pollution problems came even later.

Now the climate has changed. Books, articles, reports, and legislation on pollution control threaten to inundate us. As Professor Kenneth Boulding of the University of Michigan has suggested, the principal pollution problem is "the pollution of our information system."

The attention being given the problem of environmental pollution is heartening, primarily because much of the writing is devoted to specific and—for the most part—thoughtful suggestions for pollution control and abatement programs and techniques.

Consider the following five reports, all published within the last year:

1. "Restoring the Quality of Our Environment," a Report of the Environmental Pollution Panel, President's Science Advisory Committee, November, 1965.

2. "A Special Report on Water Supply and Pollution Control—Are We Ready for the Future?", from *Water Works and Wastes Engineering*, Volume 2, 1965.
3. "Steps Toward Clean Water," a Senate Public Works Subcommittee Report on Air and Water Pollution, 1966.
4. "A Ten-Year Program of Federal Water Resources Research," prepared by the Federal Council for Science and Technology, Committee on Water Resources Research, February, 1966.
5. "Waste Management and Control," National Academy of Sciences, National Research Council, 1966.

These reports demonstrate concern. But now we need action.

My concern, as a legislator, is with the creation and enactment of laws which will make possible more effective control and improvement of our environment. The jurisdiction of my subcommittee is focused on the authorization of air and water pollution control programs which include enforcement authority, grants for construction of abatement facilities, grants and contracts for research and development, grants for State, interstate and local control programs, and the creation of suitable institutions—within the context of our Federal system—to implement the various facets of these programs.

There is, as you know, an interrelationship between air, water, and soil pollution. But the problems of each are sufficiently unique to require different scientific and institutional control techniques.

The location, geographic boundaries, condition, source, and direction of the flow of water can be identified, measured, and—within certain limitations—predicted. Atmospheric conditions are far less subject to precise measurement or accurate prediction. Polluted water can be collected, controlled, and carried considerable distances for treatment or disposal. Polluted air must be prevented at the source of emission.

This afternoon, I should like to discuss environmental improvement in the context of our current efforts to devise sound national policy and programs.

First, let us turn to the question of water pollution.

The Water Quality Act of 1965 represented one of the major steps in a national effort to grapple with the fact that water is not an unlimited resource. As Abel Wolman has put it—in his imaginatively titled *Scientific American* article, "The Metabolism of Cities"—"As man has come to appreciate that the earth is a closed ecological system, casual methods that once appeared satisfactory for the disposal of wastes no longer seem acceptable. He has the daily evidence of his eyes and nose to tell him that his planet cannot assimilate without limit the untreated wastes of his civilization."

There are those who reject this approach. There are others who pay lip service to the doctrine of pollution control and abatement—as long as it doesn't cost any money. But, fortunately for the conservation of our water resources, there is an increasing number of our citizens who are ready and willing to make the necessary investment in the improvement of water quality.

High quality water is more than the dream of the conservationists, more than a political slogan; in the right quantity at the right place and at the right time, it is essential to health, recreation *and* economic growth.

This was the philosophy of the Water Quality Act of 1965, the basic purpose of which is "to enhance the quality and value of our water resources." Prior to the enactment of this legislation, our primary concern was with repairing past damage and slowing the advance of pollution. Now, we have turned the corner, to focus on tomorrow's needs as well as today's crises.

We know, for example, that our present national water use rate is in the vicinity of 350 billion gallons a day. Our total supply of water is 1,200 billion gallons a day. The most we can extract, economically, is about 550 billion gallons a day. By the year 2000, barring major advances in re-use, we will have a water deficit of 200-400 billion gallons a day. And that deficit will not be evenly divided across the country.

The Water Quality Act is not the final answer to these needs. But it was designed to provide us with two important instruments for the establishment and implementation of a national water policy; (1) the new Federal Water Pollution Control Administration, directly responsible to a Cabinet level Secretary—since last week the Secretary of Interior—and armed with a mandate to consider all aspects of water pollution control and abatement; and (2) the water quality standards section, designed to stimulate cooperative Federal-State-local water resource planning and aimed at improvement as well as repair of those water resources.

In addition, the Act provided for modest increases in Federal authorizations for sewage treatment construction grants, a pilot program to deal with the problem of combined storm and sanitary sewage, a bonus for regional planning of sewage treatment systems and a special enforcement provision for situations where shell fish harvesting is prevented as a result of pollution.

Success in implementing the Water Quality Act and in providing additional tools for the war against pollution will depend on our skill in identifying specific pollution problems, in planning the optimum utilization of our water resources, in making appropriate decisions on the construction of effective municipal and industrial waste treatment works, and in achieving scientific and technical advances in the removal of waste and the treatment of water for re-use.

The identification of our pollution problems is not as simple as it may seem. In the past we have concentrated our attention on what we might call "conventional" pollution—human waste, organic materials from food processing, suspended solids and toxic residues from industrial processes. For the most part those wastes could be traced and controlled. Now, however, in addition to attacking these wastes, we must cope with the impact of dispersed and persistent wastes which cannot be traced to individual plants or municipal sewer systems. The "new" wastes include fertilizers, herbicides, fungicides, and irrigation residues from agri-

cultural pursuits, detergents from homes, radioactive wastes from atomic energy and research plants, and salts and other materials which wash off highways, parking lots, garages, and buildings.

Many of these pollutants are not biodegradable. They defy conventional treatment and build up in water supplies, making them undesirable and dangerous for re-use. And, as we learn more about the dangers of long-term low level exposure to some of these materials we realize that no waste substance can be written off as harmless in our increasingly crowded society.

The Subcommittee on Air and Water Pollution is aware that research in the area of detecting, identifying, controlling and treating "dispersed" and chemically complex wastes must be accelerated.

The second major area of water quality activity must come in the acceleration of our waste treatment facility construction. Several steps were taken in the first session of this Congress, including the temporary increase in grant authorizations for the sewage treatment program, and the research and development funds for improved methods of dealing with combined storm and sanitary sewage—all in the Water Quality Act. They were supplemented by the water and sewer grants in the Housing and Urban Development Act of 1965, the Public Works and Economic Development Act, and the new rural community water and sewer program under the Aiken Act, administered in the Department of Agriculture.

Any extension of the treatment systems, particularly on a regional basis, suggests the possibility of more integration between municipal and industrial waste treatment systems. We recognize that there are problems of waste compatibility, but there is evidence that in many areas economies could be achieved, to the advantage of industries and municipalities alike.

The final major area of concern is advance waste treatment and purification of water for re-use. The drought which has affected the Northeast in the past few years has accelerated con-

cern with water supplies. This is a concern the West has known for years. Technologically there are several ways of dealing with the problem. We can transport water from areas where the supply exceeds the demand. We can draw on the resources of the sea through desalination plants. We can treat our waste water and re-use it to a much higher degree than we do today.

Each method has its disciples, and the discussions of the relative merits of each sometimes approach the level of a theological debate. The general approach our subcommittee has taken is that no one system provides *the* answer, but that a combination of all three will be needed to meet different circumstances in different parts of the country.

The subcommittee on Air and Water Pollution is endeavoring to meet each of these major concerns, with new programming and increased fund authorization.

The Subcommittee's report, "Steps Toward Clean Water," documents the costs of launching an effective program of pollution control and abatement. For instance, the present level of Federal aid for treatment plants is \$150 million a year. But the Subcommittee has estimated that present needs in our major cities, alone, total more than \$1.3 billion. In 6 years this total will double.

The Subcommittee found that the national price tag for our current backlog of needed treatment facilities will be about \$20 billion by 1972. This would provide secondary treatment facilities for 80 percent of the population, plus tertiary treatment for 20 percent of the population, including some joint industrial-municipal systems. This is not, of course, the end of the problem. The total cost by the year 2000 is likely to be in the vicinity of \$100 billion.

To meet this challenge there must be a greater effort by all levels of government. To beef up Federal participation and to stimulate our States and cities the Subcommittee has made several recommendations.

These include increasing Federal authorizations nearly seven times, to a total of \$6 billion through 1972; eliminating the present dollar ceiling on Federal grants for treatment facilities; paying 30 percent of the costs of treatment facilities, regardless of the individual project price; providing a bonus to projects in which the State matches the Federal contribution; providing Federal loans for cities when the States do not share in the cost; enabling cities to apply directly for Federal help when their States do not match Federal grants; and strengthening research and development efforts for advanced waste treatment and industrial-municipal systems.

All of these proposals would support an effective implementation of the water quality standards provisions of the Act of 1965 and the advancement of sound water resources planning and development.

In addition, the President has proposed organizing the water pollution control program along river basin lines. This proposal is based partially on the Water Quality Act of 1965 and partially on the Water Resources Planning Act of 1965. It would, in effect, tie eligibility for Federal sewage treatment construction assistance to participation in a river basin plan which includes the use of water quality standards, expanded enforcement and long-term local financing arrangements.

A second major feature of the President's proposal is a tightening of enforcement procedures, including a reduction in the time required to implement enforcement actions under the present Act, authorization for subpoena powers for the Secretary in connection with enforcement procedures, provision for citizens' suits in Federal district courts where damage from pollution is alleged, and expansion of the authority of the Secretary in setting water quality standards.

Finally, the Administration's legislation provides some increases in Federal assistance for sewage treatment construction, an increase in Federal assistance in State pollution control programs,

and an increase in the authorization for Federal water pollution control research.

These two proposals are before the subcommittee. Our task is to try to put them together. This creates some problems which have been touched upon in the hearings. The two important problems are: (1) the viability of the river basin organizations proposed in the Administration bill; and (2) the funding provisions of the two bills.

What about air pollution? Our efforts to control air pollution have been slower than our water pollution control efforts. Partially this is the result of the fact that the relationship between water pollution and ill-health, economic costs and damage to fish and wildlife was far more obvious than the adverse results of air pollution. In addition, man has tended to regard the air as "free" and limitless rather than as a thin covering over the earth—proportionally as thick as the skin of an apple.

We were shocked by the deaths caused in Donora, Pa., London and New York by killer smogs. We were far less aware of the insidious hazards of long term exposure to automotive emissions, sulfurous exhausts from factories and power plants, and the gradual buildup of contaminants such as oxides of lead, oxides of nitrogen, and carbon dioxide.

Smoke and smog first called our attention to air pollution as a major environmental problem. Los Angeles and California moved in the forties, as a result of the damage and discomfort caused by smog. But it was not until 1955 that our first national air pollution control legislation was passed. That legislation limited Federal authority to research and grants for research and technical assistance to the cities and States.

The Federal program was broadened under the Clean Air Act of 1963, which included authority for additional research and technical assistance activities, matching grants to State, regional and local agencies for the creation or improvement of regulatory control programs, and a Federal enforcement program for the abatement of air pollution.

The program was further strengthened in 1965, with the enactment of controls on automotive exhaust emissions and a solid waste disposal program.

Under the automotive exhaust control legislation all new cars, starting in the fall of 1967 with the 1968 models, will be required to meet the equivalent of the present California standards. The automotive industry was reluctant to accept these requirements, but we have been assured that they can meet the deadline.

The Solid Waste Disposal Act provides for a matching grant program for research, development, and demonstration of improved methods of disposing of solid wastes. This program should also yield benefits in water pollution control.

This year the subcommittee is focusing its attention on improvement of the support program for State, regional and local agencies. We are wrestling with the problems of specific contaminants—such as sulfur and lead oxides—but we have not arrived at a consensus on the best method of controlling emissions of such compounds.

We must arrive at agreement on this point, for the evidence before us indicates that health and economic considerations demand effective and early action.

One other major problem is the continuing need for improved regional air pollution control programs. Existing legislation provides for the institution of such arrangements, but our progress to date has not been as rapid as needed. Air does not respect jurisdictional boundaries and effective air pollution control cannot be limited by such boundaries.

In conclusion, I think it can be said that we have reached the point where we have established the basic Federal institutions and programs for the control of pollution. Our major remaining problems can be summarized as follows:

- (1) How much money do we need to spend—at the Federal, State, and local level—to abate and control pollution and to improve environmental quality?

(2) What institutions will best operate to finance and manage pollution control programs within the context of the Federal system?

(3) What mechanisms should be established for detecting, monitoring and triggering appropriate controls on "dispersed" or exotic pollutants whose hazards may be long-term rather than immediate in impact?

(4) What financial incentives or penalties are appropriate and desirable in encouraging private citizens and corporations to accelerate pollution control efforts?

(5) How can we prevent overlapping, competing Federal, regional, State and local programs from impeding rather than helping our efforts to improve the quality of our environment?

None of these questions can be solved today or tomorrow. When these questions are answered, others will be raised—by changes in our environment and changes in our institutions.

The control of our environment and its improvement is and must be a constant experiment. And, within the framework of logic and the application of scientific techniques, it must remain essentially a process of trial and error.

We cannot create political institutions in the laboratory which can be set down in the world as perfect instruments for the implementation of public policy. We have a social as well as a biological inheritance, and changes in the social and political structure must be made with care. But they must be made, and soon, if man is not to waste his birthright and ignore his trusteeship for future generations.

REACTION: John A. Carver, Jr.

Senator Muskie's emphasis on the "context of our total environment," his recognition of the interrelatedness of air, water, and soil pollution, and his attention to water supply as an urgent national race against the clock, all accord with the general thinking of his counterparts in the executive branch.

I am not as sanguine as the Senator, however, that we have "established the basic Federal institutions and programs for the control of pollution," at least not in the terms in which Senator Muskie states the task.

Not fewer than eight Federal agencies carry on research related to water supply or water quality. Federal programs for assisting States with water development activities have been in the past very fragmented.

We have made improvements, notably and hopefully a major one being the river-basin approach which was recognized by the President in his message of February 23. Such an approach is also implicit in the reorganization which transferred the Water Pollution Control Administration to Interior a week ago, and it is evident in the legislation which the Senator has described.

Senator Muskie emphasizes the importance of operations, of active programs, of getting to work on the pollution, rather than on the organizing to get to work on pollution. I agree.

If history is a teacher on how new institutional arrangements start to function, we can expect a lag in direct proportion to the complexity of the arrangements affected, and in water and air pollution this is complex indeed.

The dollar figures which Senator Muskie uses—figures which a disciplined executive branch must use most carefully—say to me that Senator Muskie would make the quality of our environment a truly national objective, one as direct and positive as, say, the drive a couple of generations ago to see that every Ameri-

can household had electricity. Another more current example is the drive to get to the moon.

Each of these is more than a governmental goal, and certainly more than a private goal—each requires a massive mobilization of both public and private resources. To borrow another analysis directly from Senator Muskie, our environmental goals involve an enlargement of the responsibilities of government, a readjustment of the levels of government, setting quality goals, more research, and a lot of money.

Presidential Adviser Walt Rostow has opined that a mature economy makes choices about what it wants to do with the wealth it generates after it has ceased accepting the extension of modern technology as a primary objective. He says it may choose among offering, by public measures, increased security, welfare, and leisure to the working force, enlarging private consumption, and seeking enlarged power on the world scene.

The United States opted, says Rostow, for the second—enlarged private consumption—first in the 1920's and again in the 1950's.

I think the universal concern which Senator Muskie describes for the quality of our environment may represent a reaction to that second option and a surge toward the first option of public measures for the general good. Or, perhaps, it represents a new fourth option—to renew and repair past damage and to prevent new damage to the quality of our life. Certain it is that the magnitude of the task we now face is a direct resultant of our whole-hearted commitment toward more automobiles, more consumer goods of all kinds, new and exotic materials, intensified agricultural practices, and the like.

Traditionally, great wealth of an economy has led to a decreased birth rate. The reversal of this "law" has magnified the problems in a way not dreamed of in the past.

In the level of expenditures Senator Muskie speaks of we can expect, in the drive to improve our environment, some of the same kinds of results our phenomenal growth in the "standard of living" gave us: that growth made automobiles and petroleum

the sectoral leaders of our economy. Cleaning up pollution is a challenge big enough to give us new sectoral leaders of our economy—whole new industries built around waste treatment technology.

In recent months, in furtherance of the President's program for new excellence in planning, programming, and budgeting, we've been experimenting in Interior with an analysis of our myriad programs which relate to the quality of environment. This experimentation reflects the increased emphasis which we feel these programs must receive in the future.

But that is a whole new subject!

REACTION: Dean W. Coston

No one can argue the basic correctness of Senator Muskie's approach to the combined and interrelated approach to the problems of the American environment. Nor can we criticize his emphasis on the need for rapid and massive actions to assure a sufficient supply of water for all national needs.

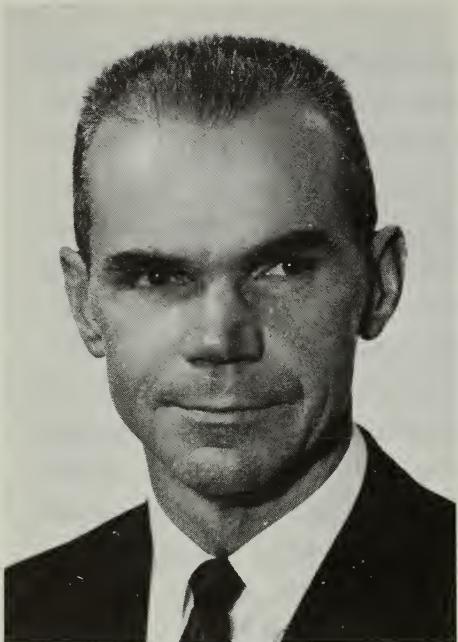
I would like to distinguish, however, certain pollution questions which I believe have received less attention. The gross pollution of the environment which arises from production of wastes has been well identified, and in many ways, solutions to these problems are known and possible. This assumes, of course, that we are prepared to make the commitment of resources needed to construct the works required for abatement, and that we are prepared to use provisions of law at all levels of government to require adequate systems for the disposal of wastes, airborne, waterborne, or solid.

The extent of the investments, public and private, needed to control wastes, is a staggeringly large amount—yet we cannot argue that these investments should not be made. We can argue, and have argued for the past several years, about the best system for making the investments and the proper mix of Federal, State, and local public effort and private capital requirements.

We have not yet, however, gained as clear a perspective on another set of environmental problems—pollution which occurs not as the waste products of human activities, but which is deliberately introduced into the environment for specific reasons. Substances in this category are not normally considered as pollutants—drugs, food additives, pesticides, agricultural chemicals—yet, because of "side effects" as yet poorly understood, frequently long persistence in the environment, and possible synergistic effects, these substances present an increasingly complicated problem in environmental protection.

In this area, as opposed to waste disposal, there has been an increasing tendency to require "premarket clearance" of the substance. In general, the burden of proof of safety rests with the advocate of the compound, and the conduct of the needed research into adverse effects is carried out by the manufacturer. The data is then reviewed by the public agency and a decision is reached.

Unfortunately, too many of these substances have been introduced into the environment without adequate understanding of their effects on the ecosystem, and for some, such as detergents, no advance proof of safety could be required under law. We should not forget, in our concern for the control of wastes, that the deliberately introduced pollutants may in the long run represent a more serious hazard to the health and welfare.



JOHN T. MIDDLETON

Director of the University of California's Statewide Air Pollution Research Center. Formerly, he was Chairman of the Departments of Plant Pathology at the University of California, Riverside and Los Angeles. He is a graduate of the Universities of California and Missouri. Was the first to recognize smog damage to plants as an economic factor in agricultural crop production in southern California. He has served as a special consultant to the U. S. Public Health Service and advisor to the World Health Organization. He is a member and past chairman of the California State Motor Vehicle Pollution Control Board, a member of the National Advisory Committee on Air Pollution to the Surgeon General, and a consultant to the U. S. Office of Science and Technology.



JOHN HERBERT HOLLOWMON

Assistant Secretary of Commerce for Science and Technology since 1962. From 1946 until his present appointment, he was with the General Electric Company in research and management. He holds the B.S. degree in physics and the D.S. degree in metallurgy from the Massachusetts Institute of Technology. He is a member of the Federal Council for Science and Technology, consultant to the President's Science Advisory Committee, and chairman of the Interdepartmental Committee for Atmospheric Sciences. He has received many awards and honorary degrees for his scientific contributions.



THOMAS F. MALONE

Second Vice President, the Travelers Insurance Company, since 1964, and prior to that Director of the Company's Weather Service and Weather Research Center and Director of Research. Earlier he served as instructor, assistant professor, and associate professor in the Department of Meteorology at Massachusetts Institute of Technology, where he received his D.S. degree in meteorology in 1946. Dr. Malone is past President of the American Geophysical Union and of the American Meteorological Society. He is Chairman of the U. S. National Commission for UNESCO and the Committee on Atmospheric Sciences of the National Academy of Sciences.

CONTROL OF ENVIRONMENT

Economic and Technological Prospects

INTRODUCTION: James M. Quigley²

The preceding two lectures in this "Environmental Improvement" series have established that man can adapt, though not always happily and healthfully, to the vastly changed environment of today; that from this point on he must improve his environment to avoid certain hazards, the severity of which can only be written with time; and that, in any improvement undertaken, the orderly processes of Government leadership and institutional knowledge must be brought to bear.

Today, in this third of the series, we are to explore the economic and technological prospects in environmental control.

Whatever course man pursues toward environmental control, he can go only as far as the amount of money he can and is willing to pay. Even then, his progress will be limited to the technology and expertise he has thus far developed to deal with the mal-practices which degrade and the toxic substances which invade his environment.

My own major concern, water pollution, for example, is going to cost the Nation as a whole a great deal of money, in terms of both construction and research, to bring it under control. The reason it is going to cost so much is because the job itself has been too long neglected, even as the number of people in general, and

² Commissioner, Federal Water Pollution Control Administration, Department of the Interior.

urban dwellers in particular, has gone up and up to quite staggering proportions. Added to this is an even greater increase in industrial developments.

The public must be brought to view environmental controls not in terms of the staggering sums the remedial measures are going to cost, but in terms of the benefits man will derive from them. Actually this already is largely the attitude we are seeing reflected in many quarters.

Research and development in my own field of water pollution control will have an important bearing on economics and on overall solutions; at the same time we must recognize that we have done but a fraction of what can be done under existing technology. In water pollution—as in the whole area of environmental control—it is imperative that we push full speed ahead, using present knowledge while developing new control technology to clean up and make more useful as much water as we can, for as many people as we can, if the Nation is to continue to grow and expand.

Actually we have barely scratched the surface. Only in very recent years has water pollution become a matter of major national policy and concern. Its meteoric rise in the Federal structure is indicative of the acceleration which must apply throughout our environmental control effort. In the case of water pollution control, this attention and acceleration has opened up whole new avenues to solution of the problems. It is providing badly needed fresh ideas, approaches heretofore undreamed of, and real action where in the past there has been only stopgap or no action.

This, then, would seem to brighten considerably our prospects for "breakthroughs" in the economic and technological aspects of controlling our environment.

SPEAKER: John T. Middleton

Man's exploitation of land, water, and air has brought about serious pollution of his environment. The unfavorable alteration of his surroundings directly affects man and other living organisms as well as the quality of the land, water, and air resources. Man must now spend much time and large sums of money to restore the quality of his environment; he must also bring about control of the environment quickly so that, as René Dubos recently said, ". . . the environmental changes that he brings about do not outstrip his adaptive potentialities . . . and that they do not decrease the qualities of his life."

Pollution of the environment comes primarily from the interaction of land use with the demands placed upon water and air. The alterations are both chemical and physical in nature. Farming, water resources development, the building of cities, and construction of transportation systems not only alter the land surface but affect air temperature, density, and movement. The dependence of industry and metropolitan growth upon combustion results in the pollution of water and air by increasing the amount of specific chemical compounds already present as well as adding new ones. Pesticides used in agriculture, the home, and industry constitute an original pollution burden since they do not naturally occur in air, water, and land. Clearly, environmental pollution is a social problem and while man individually may help to reduce the contamination of his environment, needed and effective control can only be achieved by concerted social and political action. Senator Muskie emphasized this point when he said, "In a society as complex as ours, where practically everything we do to maintain life and produce goods and services results in contamination of the environment, public decisions and actions are needed to improve the environment."

This paper will review a few examples of land, water, and air pollution, and assess the economic and technological prospect of

restoring the quality of those resources and the suitability of legislation to achieve the needed control.

Land

Man has continually gained greater control over his land environment according to his needs. Land use has changed with man's growth and development; today it is primarily used for pasture, range and agricultural crops, timber, wildlife, outdoor recreation, industry and urban development. Land use is principally controlled through ownership. Land ownership in California has been shown by D. G. Aldrich to be about equally divided between government and the private citizen. Government-owned lands are primarily dedicated to public domain, recreational areas, military reservations, and schools; more than 90 percent of privately owned land is used for agriculture. Each year more and more land is used for urban and industrial development. In 1850, the addition of 1,000 people to a city required an additional 10 acres of land. In 1960, 200 acres were needed for each additional 1,000 people. Population growth in California today converts 375 acres to urban use each day. About 3 percent of the State's land area is now dedicated to industrial and urban uses. The continued depletion of prime agricultural land for urban development and the improved and more intensive use of agricultural land for food production result in serious pollution of land, water, and air.

Some measure of land quality control results from actions of public agencies concerned with soil conservation and commodity support. The control of land, water, and air pollution by agricultural operations requires improved pest control practices, with emphasis on bioenvironmental control. The ever-increasing use of land for industry and urban expansion so pollutes the air that economic crop damage throughout the Nation has been estimated to be as much as \$500,000,000 a year. Not only have land use

controls been unable to direct urban expansion to use the vacant land that exists within communities and the hillsides above the fertile agricultural lands, land planning and zoning have failed miserably in making best use of land to minimize pollution effects on water and air.

Water

Man's dependence upon water for life as well as for agriculture, transport, power development, and manufacturing has led him to live on waterways or near water sources. In turn, man has used water for a host of sanitary purposes, including the disposal of wastes from domestic and commercial activities. Serious changes in water quality have resulted, depending upon the nature and extent of the water supply, the number and kind of users, the geographic placement of water users along the waterway, and the degree of pollution control. Man's concern with water quality differs from place to place and often depends upon his social and economic growth. While his concern with personal health requires water of high purity, he may also be concerned with odor, trash, and off-color nuisances, as well as the suitability of water for agricultural, industrial, and recreational use.

The amount and distribution of water and the degradation of its quality through pollution can be fairly well predicted since the source, flow, and course can be identified and measured within a specific watershed. Its ownership is much more difficult to determine than that of land, and consequently its use is often poorly considered and controlled. Most domestic and industrial users pay for water supplied through an organized service system. There are, however, many significant water users who pay nothing for this commodity so essential to their personal and business needs; typically there is no monetary charge for water used and degraded by municipal and industrial waste and sewage disposal, and by thermal and nuclear power generation.

The pollution of water becomes cumulative with water carrying an increased burden as it moves downstream, regardless of the degree of pollution control on a riverway. While the adverse effects of water pollution may be seen along the waterway, the most serious effects are seen in the estuarine zone where the pollutants which have been carried long distances down rivers flowing to the sea, end in an estuary, and become trapped as the result of river deposition and washings from the sea. The importance of these lowland areas bordering the seacoast as areas where pollution problems merge and concentrate, is shown by the fact that about 60 percent of the people in the United States live within a border 250 miles wide along the coast of the Atlantic, Gulf of Mexico, and the Pacific; two-thirds of the factories making agricultural pesticides, organic chemicals, and paper pulp, and more than half of those making inorganic chemicals and petroleum products are located in the coastal States. Further, the estuarine area and its continental shelf supply nearly 60 percent of the country's seafood products with an annual value of about \$225,000,000. These coastal zones form an important recreational area, providing fishing and hunting for nearly 4,000,000 people annually, as well as river, park land, and coastal sanctuaries for a great variety of wildlife. The potential adverse impact of water pollution thus is not limited to man, but affects other living organisms upon which man depends for sustenance and well-being.

Control of water quality thus requires the establishment of water quality criteria and standards based on needs of the ultimate downstream user and on the pollution effects of all effluents introduced into the waterway system. Control processes must be designed to reflect the chemical nature of the pollutants, alone and in combination with other pollutants, their life and toxicity. They must be varied to permit the requisite abatement of harmful organic and inorganic compounds, saline materials, solids, debris, and a variety of trace substances, such as chemical

synthetics, and metals such as copper and lead. Consideration must also be given to the curtailment of surface waste waters which add silt, nutrients, pesticides, and salts from agricultural lands. While some polluting materials are diluted to nontoxic levels as they flow with the stream, others, such as pesticides, become concentrated and accumulate in water-inhabiting plants, animals, and fish. Some of the complex of inorganic and organic wastes which move with the stream become metabolized and degraded into innocuous products, while other less toxic pollutants may be transformed into toxic intermediate products. Still other forms of biologic activity alter the properties of water by reducing the amount of dissolved oxygen, changing its acidity, causing turbidity and a variety of other conditions that disturb life in a water environment.

Concepts and methods for water quality control must be based upon the dynamic nature of the waterway as well as abatement of specific pollutant effluents. Once the water quality criteria have been determined and water quality standards established, the water resource must be managed within the total watershed by controlling its use by domestic, industrial, and governmental users. Important tools for pollution control include the use of collective disposal systems for economic waste treatment, water salvage and salinity control, streamflow management, the determination of areas in which no waste disposal will be permitted, and impounding systems for specific pollution control. Streamflow control for dilution of contaminants, impoundment for decontamination and desilting, as well as thermal and biological equilibration for water quality improvement would in turn contribute to improvement of estuaries and bays and the reinstatement of estuarine and offshore areas as important for marine fishing and recreational use. A system of taxing or placing a charge on the nature and amount of effluent released into a watershed would give incentive for reduction in effluent pollutants; an increase in effluent fee based on regularized water quality improvement and

length of effluent disposal would assure reduction in effluent volume and concentration and preclude the dumping of wastes for a price. Equally important is the forgiveness of tax on effluent waste control equipment as an incentive for restoring the quality of the water environment. The sale of water for domestic and industrial use and income from recreational use of the waterway should be established to support the cost of water-resource management. While a much better understanding of the biological and chemical dynamics of the moving water resource would improve an integrated water use program, enough is now known to instigate operations on a watershed-estuarine basis and relate supply to demand through systems analysis, as is planned by the Delaware River Basin Commission.

Air

Air, a mixture of gases and liquid and solid particles forming a thin envelope around the earth, is a natural resource vital to man, essential for animals and plants, and necessary for man's community, domestic, industrial and agricultural activities. The physical properties of air, such as temperature, water density and movement determine the growth and development of plant and animal life and thus become a significant parameter of man's use of his land and oblige him to adapt to his environment. These properties affect the nature of the earth's surface and thus the success of the agriculturist and forester and commercial and metropolitan development. The chemical nature of air, particularly its oxygen, carbon dioxide, and water vapor, also directly affects man and his community, his foods, forests and land which are an integral part of man's economic, recreational and esthetic well-being.

The quantity of air is yet another factor determining the value of the air environment. While some scientists believe the earth's atmosphere extends to the magnetosphere some 35,000 miles be-

yond the earth's surface, 99 percent of the total mass of the atmosphere is found within 19 miles of the earth's surface. The body of air with the greatest effect upon man is that of the troposphere which extends above the earth's surface only 7 miles and contains 80 percent of the total atmospheric mass. The amount of air directly available to man is, in fact, much less. Its availability is dependent on geographical and meteorological factors not as yet subject to man's control, which define the airshed and determine the rate of diffusion and mixing and thus the concentration of air pollutants. These factors, including the frequent presence and persistence of a confining inversion level, influence airflow and mixing and the vertical dispersion of air contaminants.

The quality of air is determined by the uses made of air and by the pollutants injected into it by man. A differing amount of air is consumed in the process of combusting various fuels: 1 pound of gasoline requires 158 cubic feet of air, 1 pound of oil requires 166 cubic feet, 1 pound of coal requires 186 cubic feet, and 1 pound of natural gas requires 248 cubic feet of air. It has been estimated that fossil fuels used throughout the Nation during one year require 3,000 cubic miles of air each year of which the motor vehicle uses 640 cubic miles, or about 21 percent of the total.

While some degradation is caused by contamination of air by pesticides and chemical manufacture, by far the greatest degradation is brought about by the use of air to support combustion. The principal pollutants from combustion for the development of electrical energy and the propulsion of motor vehicles, and the manufacture of goods are liquid and solid particles, oxides of sulfur and nitrogen, organic vapors, and carbon dioxide and monoxide. The nature of the fuel and the kind of combustion affect the kinds of products formed and consequently the amount of pollution emitted from the combustion source. A pollutant released in large quantities throughout the Nation is sulfur dioxide; John Ludwig has estimated it to amount to 23.3×10^6 or

23,300,000 tons a year. The principal sources of sulfur dioxide and the current annual amounts derived from fuels and manufacturing processes are:

Coal	14.0×10^6
Petroleum	4.8
Metallurgy	1.7
Petroleum Refining	1.6
Coke	0.5
Chemical	0.7
	<hr/>
	23.3×10^6 tons

The largest single source of sulfur dioxide is that from the generation of electrical power. In 1980 it is estimated that electrical energy development will be three times that of 1960, and that a 50 percent increase in sulfur dioxide will result, contributing 36.0×10^6 tons of sulfur dioxide to the atmosphere each year. The average motor vehicle in the process of combusting fuel produces about $6\frac{1}{4}$ pounds of contaminants per day, or in California alone 3.45×10^4 or 34,500 tons per day of organic vapors, oxides of nitrogen and sulfur, carbon dioxide, carbon monoxide, and lead.

The amount of pollution in an area depends upon the degree of urbanization and the amount of industry, as well as the nature of the fuels used. In Los Angeles, for example, fuels are typically low in sulfur because of natural supplies and regulations controlling sulfur content. Nonetheless, there are 0.16×10^6 or 166,000 tons of sulfur emitted each year, or about 455 tons a day; of this total 7 percent is estimated to come from the motor vehicle. Each day there are 835 tons of nitrogen oxides formed, of which a little more than half originate from the motor vehicle, with power plants supplying the principal balance. The organic vapor losses daily amount to 2,755 tons, of which 70 percent come from the motor vehicle and most of the balance from solvent usage. Carbon monoxide emissions daily amount to 10,660 tons, of which

all but 330 tons come from the motor vehicle. Carbon dioxide emissions have not been estimated. Of the total tons of emissions in the Los Angeles area, about 1,500 daily originate from industry, while 10 times that amount, or about 15,000 tons, are released by the motor vehicle. The relative importance of these two sources of pollution in any area depends upon the degree to which each is controlled; in any case it is quite clear that combustion represents a sizable part of the total pollution burden of the air.

The significant reduction in pollution from industry in Los Angeles has been achieved by the County Air Pollution Control District's program over the last 18 years. For that period the total county government expense amounted to \$38,000,000 or \$5.57 per person at the present census count. Air pollution control equipment for the same period has cost \$118,000,000, or about 15.7 percent of the total manufacturing equipment cost; other costs for air pollution control result from manufacture process changes, fuel supplies, and market restrictions for some goods and byproducts.

Weather modification has sometimes been suggested as a means for alleviating the air pollution burden. Morris Neiburger has calculated that within the Los Angeles Basin the energy required to eliminate the inversion over the entire basin is 1.32×10^{16} calories, which is equivalent to burning at one time, with 100 percent efficiency, 1,270,000 tons of oil, or the total amount of crude oil produced in 12 days in the Los Angeles area. He also calculated that a one square kilometer "hole" in the inversion layer could be produced by 3.3×10^{12} calories, equivalent to the burning of 320 tons of oil. However, to maintain the "hole" requires the same amount of energy as that needed to eliminate the inversion completely. An improvement in air pollution in the Los Angeles Basin could also be obtained by increasing the windspeed from its average 6 miles per hour in summer to 9, through the use of electrically driven fans. In any one day this would require 16,-

000,000 kilowatts, or the equivalent of the electrical energy developed by at least 12 simultaneously operated Hoover Dams. These energy requirements become more understandable if one considers that the weight of air in the Los Angeles Basin amounts to about 200,000,000 tons. It would appear, therefore, that within the foreseeable future, there is no ready way of increasing the air availability to populated areas situated in geographic locations with aggravated meteorological conditions. It appears necessary under our present control of the weather to accommodate the population to the air resource, rather than the resource to the population.

The quality of air within a given airshed thus depends not only upon the nature of pollutants emitted into the atmosphere but upon the quality of the air supply and previously mentioned geographical and meteorological factors and their effect on the movement and dispersal of the contaminants. Effluents emitted into the airstream within the airshed interact with subsequent emissions from different contaminant sources at different points within the airshed. Pollutants released by sources located in a highly developed area subject to restricted air ventilation have a much greater adverse impact than emission sources located in an open site with maximum air movement. Pollutants persist longer and are spread over greater distances when they are emitted from a number of emission sources distributed at various points within a particular airshed. One of the results of multiple pollution sources is the formation of photochemical air pollution created by the combination of nitrogen oxides and organic vapors in the presence of sunlight. Photochemical air pollutants thus formed include ozone, peroxyacetyl nitrate (PAN), aldehydes, and organic acids; these are readily produced in the atmosphere by the photolysis of unsaturated hydrocarbons and nitrogen dioxide. Under similar conditions these same products are produced slowly from aromatic hydrocarbons, and not at all from most paraffins. Different organic components and their different reaction rates

with nitrogen oxides determine the chemical composition of the moving pollution cloud and the variety of products and manifestations observed in different areas, and distances from the principal emission source. An example of the differing effects of this syndrome of varied reaction and decay rates is seen in the Delaware River Valley where PAN is found in Philadelphia with small amounts of ozone, and where ozone only is found in the Upper Delaware River Valley, probably attributable to the movement of the pollution cloud away from the metropolitan area and into the rural environment without much contaminant addition to the originally urban-formed cloud. Another example of this syndrome may be the common occurrence of PAN and small quantities of ozone in Washington, D. C., and of ozone without PAN some distance away. The prevalence of PAN, ozone, and aldehyde throughout the Los Angeles area may be the result of more or less continuous injection of contaminants from the extended urban area into the moving air resource cloud within the confined airshed.

Some variations in air pollution and its manifestations in different parts of the country are related to the differing fuel utilization in these different areas, for example, the use of coal, fuel oil, or natural gas. Another difference in the type and intensity of pollution is seen in the relatively higher levels of sulfur dioxide on the Eastern Seaboard than in California. Because photolysis of sulfur dioxide, alone or in combination with reactants from the photolysis of nitrogen oxides and hydrocarbons, leads to the creation of particles, visibility reduction characterizes pollution in New York and the Delaware River Valley. This visibility reduction differs from that familiar to Californians in that the California pollution typically contains eye-irritating aldehydes and PAN resulting from the reactions between organics and nitrogen oxides rather than visibility reduction without significant eye irritation from the photolysis of sulfur dioxide. The quality of air over the land and for many miles downwind in the moving air

mass is determined by the quality of the original air supply and the upwind emission sources. The nature and extent of pollution is a function of the kind, number, and distribution of emission sources, and hence pollution is a function of land use.

The effects of polluted air are many and varied and include increases in atmospheric carbon dioxide with its alleged effect upon climate, corrosion of metals, deterioration of buildings and fabrics, the cracking of rubber, reduction in visibility, damage to forests and agriculture, injury to livestock, jeopardy and damage to the health and well-being of man, loss of beauty, and spoiling of the air environment itself. The importance of these effects provides the motivation for controlling and restoring air quality without sole regard to quality improvement costs.

It has been estimated that the direct costs of air pollution amount to \$65 per person per year. Such a figure does not include many of the indirect and often immeasurable costs. For example, many vegetable and flower crops can no longer be grown near large cities; California lemon growers in 1965 were denied \$533 an acre because of reduced crop yield attributable to photochemical air pollution; prime tobacco leaf production has been significantly reduced in sections of the country; the vigor and vitality of forests on the east and west coasts have diminished, and the beauty and freshness of recreational areas have been destroyed in many States. These facts should provide ample evidence of the need for air pollution control. The impetus for requisite social and political action, however, unfortunately appears to depend on the more dramatic evidence of air pollution effects, such as direct effects on personal health and life. Acute air pollution episodes have caused deaths in Donora, Pa., and increased mortality among the ill and aged in New York and other U. S. cities. Although research has shown that the running activity of experimental mice is reduced 10 percent, that their lungs are more susceptible to infection, and that the pulmonary resistance of a guinea pig's lungs is increased during periods of air pollution, that man suffers eye

irritation and reduction of visual acuity, that the transport of oxygen by blood is upset, that pulmonary resistance and the work of breathing is increased, and that man's work performance is reduced during periods of pollution, the public remains apathetic about air pollution control. This is the time to do much more than control pollution at its source, it is time to constructively use and manage the limited air resource which serves mankind and all living creatures over the entire earth.

Recognition of air pollution as a social and political problem, and the enactment of legislation to control air quality have occurred at both State and national levels. Enabling legislation to permit local jurisdictions to cope with specific pollution problems was enacted in California in 1947; legislation permitting regional control of air pollution was passed in 1955. Federal legislation in 1955 authorized Federal research in air pollution, and grants for research and technical assistance to cities and States. The California legislature in 1959, enacted legislation requiring the promulgation of ambient air quality standards and emission standards for motor vehicles, and in 1960 passed the Motor Vehicle Pollution Control Act. Under the wise and able guidance of Senator Muskie, the 1955 Federal air pollution control program was significantly improved and broadened with the passage of the Clean Air Acts of 1963 and 1965. Control of the air environment further requires the establishment of source emission standards designed to insure clean air as defined by valid and adequate air quality criteria and ambient air quality standards.

California has adopted source emission standards for motor vehicles but not for other pollution sources. Air quality standards must be established for all source emissions for airshed application with especial consideration of the downwind user and his economic and social needs. Adoption of such source emission standards by interstate, State, and local governments now depends upon the development of national air quality criteria by the Federal Government; significant progress in this important matter

is being made under the leadership of V. G. MacKenzie, Chief, Division of Air Pollution, U. S. Public Health Service.

While much is to be gained in air quality improvement through control of specific pollution sources, this approach at best is short-sighted and does not give adequate consideration to present knowledge of air supply and airshed limitations. Improvements in specific source control can be gained by process improvement, control of fuel quality and composition. For example, some control of sulfur oxides emissions has been achieved by treatment of the effluent; very little, however, has been achieved in the reduction of sulfur oxide emissions through removal of sulfur in coal and fuel oils, or from the expanded use of natural gas inherently low in sulfur. Changes in the composition of gasoline may be needed to reduce the photochemical reactivity of hydrocarbons lost to the air through evaporation and perhaps through exhaust emission; still other changes may be needed if lead and other gasoline additives emitted to the air through vehicular exhaust are shown to be deleterious.

Motor vehicles represent a significant pollution source throughout the Nation, and particularly in major metropolitan areas where motor vehicle population is highly concentrated. Control of motor vehicle crankcase hydrocarbon emissions began in California with the installation of mechanical devices in 1961; the same systems were used nationally in 1963. Hydrocarbon and carbon monoxide emissions have been significantly reduced from new car vehicular exhaust in California since September 1965. Beginning in September 1967 exhaust emissions will be controlled on new cars throughout the United States. The average 1966 car with both crankcase and exhaust control systems costs about \$50 more than a car without pollution controls and its annual maintenance is increased by about \$5.00; this beneficial reduction in emissions costs little more than $\frac{1}{2}$ cent per mile, or somewhat less than 10 percent of the average operating cost per vehicle mile.

The increasing number of motor vehicles, and the increasing size of engines will soon offset the benefits of present controls unless emission standards are significantly lowered, cleaner automotive power plants produced, and alternative transportation systems provided. The relatively low ratio of people per motor vehicle in Los Angeles, about 2.25 to 1, compared with New York City, about 7 to 1, accents the importance of the motor vehicle as a polluting source in California and the urgency for more stringent source emission standards in that State than may be required nationally. California exhaust emission standards are scheduled to be reduced in 1970 for hydrocarbons from 275 p.p.m. to 180 p.p.m., and for carbon monoxide from 1.5 percent to 1 percent; by 1980 they may have to be reduced to less than 100 p.p.m. and 0.5 percent with added provision for strict control of nitrogen oxides. Engine modification and design improvement of the reciprocating gasoline power plant may achieve 1970 emission requirements, but greater changes will be required to meet the 1980 air quality needs. The use of catalytic systems on improved engines is one important method available for exhaust gas reduction. The gas turbine engine offers another opportunity for engine waste gas cleanup. Improvement in diesel power units offers yet another means of reducing motor vehicle caused pollution.

Electric power plants offer the greatest prospect of significantly reducing noxious motor vehicle emissions. The zinc-air batteries and the hydrocarbon fuel cell must be realistically considered as future motive power sources. The present economic and technological status of acid lead batteries suggests that these cleaner power plants may be used now for short mileage, low speed routes in urban areas. The replacement of gasoline-powered reciprocating engines with battery driven electric engines for specialized purposes, such as mail and product delivery, and local transportation by governmental and private agencies, should be considered as an immediate way to reduce motor vehicle pollution.

The perpetuation of fuel tax to assure the expansion and enlargement of highway systems seems inappropriate and ignores the need to develop useful mass transit systems; consideration should be given to the rededication of this tax for rapid or mass transportation systems which will significantly contribute to air pollution control.

Further improvements in control of air pollution require consideration of the location of pollution sources in relation to the characteristics of the airshed. Judicious location of power plants, industry, freeways, green belts, and residential areas is an increasingly important consideration in the maintenance of an adequate air resource. Urban area planning is now recognized as a vital factor in air pollution control.

The national trend towards the development of very large fuel powered electric generators poses a serious threat to air quality in cities and their contiguous rural areas because of the large volume of air used and the great quantities of pollutants emitted. Such power generating facilities should no longer be constructed in congested areas, nor along sea frontiers, or river basins where airflow assures the movement of effluents across urban areas and throughout the airshed. Rather, they should be located at a distance from the urban areas and near fuel supplies with provision made for the transportation of electricity to the areas of need. The use of atomic energy as a fuel for electrical generation appears to be safer and cleaner than coal-fired generators despite the problem of solid waste disposal; this would permit power generation within the airshed to be served.

The significance of highway location in air pollution formation and concentration should be a guiding factor in the planning of future highway systems throughout the country. Attention should be given not only to the location of highways in relation to the airflow and the potential thus created for the accumulation and buildup of air pollutants, but also to the design of highway routes in order that pollution may be reduced through speed control.

Pollution created by the motor vehicle is roughly inversely proportional to speed; an increase in speed from 20 to 30 miles per hour yields about a one-third reduction in pollutants, while a change from 20 to 40 miles per hour brings about a twofold reduction in pollution. Freeway design should provide for open space, beautification by plantings, and the development of green belts since they afford a means of air cleansing and a concomitant reduction in pollution. Not only do motor vehicles produce pollutants affecting the air environment, but they appropriate land for roadways, building access, parking, and maintenance. These demands in turn affect the structure of the city, land values, and revenue; this is well illustrated in central Los Angeles where one-half of the downtown area is dedicated to the mobility and handling of the motor vehicle.

The location, structure, and size of cities have a significant effect upon air quality. Cities located in confined geographical sites or locations in which meteorological factors limit air movement and contribute to air stagnation have more serious air pollution problems than those located elsewhere. Philip Leighton has shown the effect of city configuration to have a significant and direct effect upon the area affected by metropolitan pollution. Cities that increase in size vertically have about one-half the air pollution potential of those that increase to the same extent horizontally. Planning a city with parks, open and landscaped avenues, and regularized planted open space, all contribute to improved ventilation, improved distribution of pollution sources, and faster diffusion of airborne contaminants. Francis Herring reports that it is not too soon to consider the establishment of "satellite cities" which will provide self-contained employment, residential and recreational opportunities; such cities would have open intervening space contributing to air quality improvement and would permit the worker to reach his place of employment in a shorter time, thus using less air polluting fuel and providing him more time for cultural and recreational experiences.

Control of the air environment must be based on the airshed and its capacity to receive, transport, and discard pollutants. Determination of this capability of the air over a particular geographical area will then permit a social and political decision as to the allowable growth in population and resource utilization needed to sustain that population's economic and social goals. While the body of scientific knowledge as to the causes and effects of air pollution and the many recent technological advances in control methods permit significant reduction in air pollution, there is need for further understanding of the interacting effects of diverse pollutants and the air cleansing system. Even more important is the need for social and political action. Only with a public understanding of the air pollution problem will we obtain the effective political action and community acceptance of air pollution control measures so essential to the transformation of technical information into social action for best use and management of the air resource.

Conclusions

While present practice of local pollution control by local agencies is effective for specific limited sources of pollution, it is not a satisfactory system for handling the quality of the environment on a significant areal or population basis. Acceptance of the principle of resource management for the most beneficial use requires that programs designed to restore the quality of the environment be established for naturally definable geographic and meteorological areas in which the entire population is involved. Since management of resources on such a basis would result in the most beneficial use for the public, extant local government bodies should yield local control to higher or multigovernment control bodies whose jurisdictional boundaries conform to the problem area. Quality standards established on a quantitative basis are necessary in order that the resource management agency can strike an appropriate balance between resource input and output. It is

inimicable to resource management that the quality of the environment be upheld primarily at the expense of the polluter and not at the expense of the general public. Free access to air and water has allowed their indiscriminate use, permitted their general contamination and has engendered a general disregard for their quality. The development of environment pollution control on a regional air or watershed basis permits area-wide quality standards to be adopted and enforced in response to public need. Such control systems also enable the appropriate resource agency to effect changes in land use basic to the control of man's environment.

REACTION: John Herbert Hollomon

I should like to try first, briefly, to put the problem of air and water pollution in a little bit different perspective. The problem of pollution represents, as does the problem of traffic safety, a condition in which two things are current. One is that the population of the United States, with its population concentration in cities and its increasing industrialization, is causing the people and their institutions within the United States to interact with each other in a much deeper fashion than they have in the past. The action of one person upon another and his reactions, the actions of one industry and one company upon the rest of the society all become increasingly important.

In the language of the chemist, we used to be "a rare gas." That is to say: when we were a rural society, three, four, five decades ago, each of us, each of our institutions, was expanded, that is, dispersed throughout the country. And the interactions among us and our institutions in that society were relatively unimportant. We have now become "a condensed system." The interactions among each of us and our institutions have become increasingly more important, compared with the actions of the individual parts of the system. And secondly, with respect to such things as pollution and the social cost of pollution—whether it be in water, or air, or the pollution of the electromagnetic spectrum where the noise of radios hurts other people who wish to use the spectrum, or hampers aircraft safety—in these and other ways the actions of one institution substantially affect all the rest of us.

More explicitly, if the only people who were hurt in automobile accidents, or the only people who were hurt by air pollution were the fellows who were driving the cars, or the fellows who were polluting the atmosphere, we wouldn't worry very much about it. Because the costs and benefits would fall upon them exclusively, not upon society. But in our society the actions of one individual cause cost to the rest of us, cause cost to the society, whether

these costs be social costs, political costs, or actual direct economic costs. An essentially similar situation is the free-market mechanism in which you and I buy goods and services from each other or one industry buys from another. It does not adequately take into account these social costs.

I think the first and most important thing to recognize in respect to air pollution and water pollution is that there must be some way in which we can assess how much this social cost is, and how much benefit would come from various ways of reducing that cost. It is not sufficient to say that air pollution or water pollution are bad, which they are; and to say we're simply going to try to eliminate them. Because what will happen as we increase our expenditures, whether they be by private parties or public parties, is that while the effects of these various things will decrease, it is not entirely clear that the benefits to be reaped by this reduction will exceed the costs.

Let me make my point perfectly clear. It would be possible to reduce all accidents due to automobiles in the United States by simply eliminating automobiles. But that is not a cost which you and I are willing to pay. It would be perfectly possible to put sufficiently stringent standards on those who pollute the atmosphere—the automobile, say, or the coal-burning power plant—to reduce the pollution to any desired maximum level. The essential problem is: How much reduction is possible and at what cost? I don't mean to say that one can always measure these costs exactly, especially that human inconvenience and discomfiture can readily be measured. I do wish to raise the question: Who should determine and how is it to be determined at what cost he shall meet these standards?

Let me give a specific example. Let's suppose we wished to reduce the air pollution from a vehicle not by 60 percent as with the presently proposed \$50 device in California, but by 95 percent. We wish to do it in 2 years. I'm sure it could be done at some large cost. Even if it meant converting to another kind of propul-

sion system or the installation on every automobile of an extremely expensive chemical device, in 2 or 3 years it probably would be possible. But if that were technically feasible, who would determine and how would it be determined that these standards should be met, and what social and political process should be involved? Should it be left wholly to the Government? Should standards be set in a mandatory fashion? Or should it be left in part to the people who are affected: you and I who drive the vehicles, the manufacturer of the vehicle, the manufacturer of power, or what have you?

In summary, one of the serious problems raised in all of these questions in which the detrimental effects of our growing wealth affect all of us is how we should construct a logical and relatively quantitative system of determining what these costs are, and how we shall ameliorate them by appropriate government, political, or economic action. It's not at all clear to me that it is better to put high cost on the vehicle or to encourage the development of satellite-cities in which the concentration of vehicles is substantially reduced. It's not at all clear to me as to how one makes that choice; and whether or not the political and economic systems involved are such as to permit that choice.

From Professor Middleton's paper, I judge that his attitude is: let's get at the problem. And I say with what resource? And how shall you determine and who should determine? This to me is a serious political and social problem.

The second point I should like to make is that we have, it seems to me, completely insufficient information with respect to pollution in the atmosphere and the environment. We do not have a detailed day-to-day time description of how the atmosphere and the water are being polluted. A 100 years or so ago, we decided that variations in the weather, storm systems, variations in rainfall were crucial to the economic and social development, and that we should know what they were and attempt to predict them so that we could eventually modify and control them if that were pos-

sible. It seems to me that we have not yet taken the steps to develop adequate systems of observation and predictions and measurement of the degree of pollution and of its nature. These should be on the large scale, on river systems, air systems, and particularly on the microscale within a city, within an area. This work, conceived so long ago, is just now beginning. There are, for example, only a few stations in the world in which the CO₂ content of the upper atmosphere is being adequately determined. And yet, as you heard, there are scientists and engineer-scientists, technical people, who believe that the contamination of CO₂ in the atmosphere will substantially affect our climate. The point I should like to make is that one of the strong factors in determining what we should do about pollution is a system of observation which adequately and quantitatively describes what that pollution is on a real time basis.

A third point is that if we are to appropriately determine social and political policy, we not only need a description of what the pollution is and how it varies in time, but much more accurate knowledge of what it costs: What it costs not only in terms of physical and human discomfort and health, but what it costs to the economy. For I am convinced that the final judgment that we will have to make in some new political arrangement is how much we are willing to spend in order to reduce how much cost.

REACTION: Thomas F. Malone

Dr. Middleton has issued a trumpet call for social and political action. His enthusiasm is contagious. I would like to comment on four aspects of his topic.

In the first place, I think the most important thing he said is that in walking down this very complicated road, the most important immediate thing to do is to establish environmental quality standards. This is a take-off point. We have the technology to do it. We've had it for 100 years, ever since there was a royal commission established to study the vapors over the Thames River. It is, as Dr. Hollomon pointed out, an economic problem; it's a matter of allocation of resources. These environmental quality standards are a function, in turn, of the effects of the pollutants, the desired use of the resource affected by the pollutants, the technological capability, and the cost. And I hope Mr. Quigley will get on with his job of setting some standards for water, if the States don't do it pretty soon. But this is the first step.

I would like in my second part to supply a few figures that I wish Dr. Middleton had included. If you take our G.N.P. and reduce it to disposable personal income and normalize it with the increase of population, we've got something like \$15,000,000,000 a year extra—each year EXTRA—out of our productivity gains to allocate to whatever resources we wish. That's the supply. Now in the environmental area, what are the competing demands? In the water area, we've got a \$40,000,000,000 investment in facilities for treatment. All together we're putting in, industrially and municipally, about \$1,500,000,000 of new equipment each year. But our problem is pretty bad. We have the equivalent of the raw sewage from 50 million people every day. We're going to be out of oxygen by 1980 in all 22 basins, and the stuff we put back in the rivers is going to go up from one-fifth to two-thirds of the streamflow by the year 2000. The demand here is about an extra \$1,500,000,000 a year in facilities.

In air, if you take the \$55. figure Dr. Middleton gave us, you get a total cost of about \$13,000,000,000. We are spending about \$325,000,000. Now this is the point Dr. Hollomon was trying to get at. How much can we knock that \$13,000,000,000 down with an increment on \$325,000,000? That's where the decision comes in.

On solid disposal, we have 250,000,000,000 pounds which we're getting rid of at a cost of one cent a pound, or \$2,500,000,000 a year. We're going to have a 20 percent per capita increase by 1980. Less than one-half of the cities have effective refuge disposal systems, so you can put another \$2,500,000,000 there. These are the kinds of competing demands that are going to be made against that extra \$15,000,000,000 and there are a lot of other competing demands outside this area. It is crucial, and I would like to associate myself with Dr. Hollomon in getting at a rational way for society to make these decisions.

Now I would like to quarrel wth Dr. Middleton. I admire so much what he said that I feel I can quarrel with him. He advocated an effluent tax. I've been through this in Connecticut. We've just had a 100-man task force to do a complete survey of our water pollution problem. We're one of the better States, but we're putting in 100,000,000 gallons a day from our cities, and another 100,000,000 gallons a day from industry. I don't think an effluent tax will work. We figure it will cost us \$230,000,000 to clean this up. We propose a \$150,000,000 bond-issue by the State with a 30-30-40, that is, 30 percent-State, 30 percent-Federal (we hope, Mr. Quigley), and 40 percent-municipality allocation to get at the job. If you try to institute a system in which you get a license to pollute, you're not going to clean up the pollution. It took 30 years for this kind of a system to evolve in the Ruhr Valley, and I don't like it.

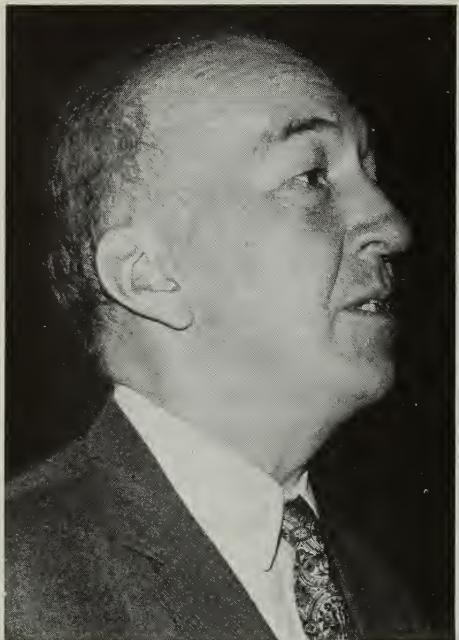
The third thing I'd like to comment on, and as a meteorologist I think I can do this, is this CO₂ content. Take this seriously. We got an increase of about 10 percent in CO₂ in the last 100 years.

An important thing is that we now have the mathematical models by which to assess these effects, and they are getting sharper all the time. Some of Dr. Hollomon's boys have made some computations. The effect of this 10 percent increase is a temperature increase of a few degrees centigrade in the stratosphere, a few tenths of a degree in the troposphere. All extrapolations suggest a 25 percent increase by the end of the century. The thing I'm bringing to your attention is that this may bring drastic climatic changes. I'm not waving the red flag of climatic changes. What I'm saying is that we now have a means of ascertaining what these consequences will be and of ascertaining the kind of countervailing purposeful action that we might take to mitigate undesirable consequences.

Finally, I would like to say a little bit about purposeful control —what Dr. Middleton was talking about. There is a new dimension which is opening up: purposeful control of environment. Two significant things have happened in the last 10 years. One is that this whole matter of tampering with the atmosphere, of controlling the weather, if you will, has emerged from the speculative stage into a stage in which the problem can be rationally attacked. This is very important. We now have the observational capability within reach, the physical models cast in mathematical form, and the computers within reach, to manipulate those models to ascertain the consequences of intervention in the atmosphere. The whole exploration now becomes a rational proposition instead of a speculative one.

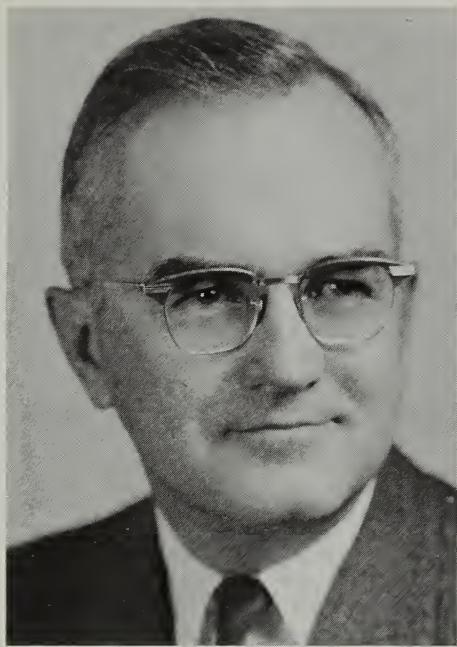
Secondly, there is evidence, and you people in Agriculture should at least be cognizant of this, even if you don't believe it, that super-cool fog can be dissipated. It seems credible that hail can be prevented, and the Russians get a 30-to-1 benefit-to-cost ratio out of this. There is some statistical evidence to indicate that precipitation can be decreased something like 10 to 15 percent purposely and consciously over limited areas.

You take these results and the fact that we now have the means of assessing in advance the consequence of a given intervention, and I think, there is a new dimension in the control of environment which I call to your attention. I do it because I'm sure that Dr. Middleton is not trying to downgrade modifying the atmosphere, and I agree with everything he said about the Los Angeles inversion. But he was picking a meteorological situation of great stability. That's what inversion is: a very, very stable air, and that's not the place you want to fool around with the atmosphere. You want to fool around in unstable conditions where it would produce a large consequence. So in the interest of at least hinting at this new dimension, I'll make that as my concluding comment.



S. DILLON RIPLEY

Eighth Secretary of the 119-year-old Smithsonian Institution, a member of the National Council on the Arts, Vice President of the American Association of Museums, and a Trustee of the Winterthur Museum. Before his appointment to his present position with the Smithsonian in 1964, he served for 4 years as Director of Yale University's Peabody Museum of Natural History. He has also served on the staffs of the Academy of Natural Sciences in Philadelphia, the American Museum of Natural History in New York, and Harvard University. He holds degrees from Yale University and Harvard University. He has many academic honors and decorations from foreign countries. A biologist and authority on birds of the Far East, he has published six books on ornithological studies. The most recent is Land and Wildlife of Tropical Asia.



JOSEPH L. FISHER

President of Resources for the Future, Inc. Before joining this organization he served (1947-1953) as economist and executive officer of the Council of Economic Advisers, Executive Office of the President. He has taught at several universities and has worked with the National Resources Planning Board. He holds academic degrees from Bowdoin College, George Washington, and Harvard (Ph.D.—1947). He is active in civic and church affairs, a member of several planning committees, and a Director of the American Forestry Association. He has written many professional articles and books.



IAN L. McHARG

Chairman, Department of Landscape Architecture and Regional Planning, University of Pennsylvania. He is a partner in the architectural firm of Wallace-McHarg Associates and has carried on a number of architectural projects as an individual. He is principal investigator, URA, Pennsylvania-New Jersey, Metropolitan Open Space Project. He holds degrees in Landscape Architecture and City Planning from Harvard University. He is the author of a number of books and articles in yearbooks and professional journals and has three in press.

THE FUTURE OF ENVIRONMENTAL IMPROVEMENT

INTRODUCTION: Roland R. Renne³

This is the fourth and final lecture in this year's "Environmental Improvement" series. The three previous lectures dealt with: (1) *Man and His Environment—Scope, Impact, and Nature*; (2) *Environmental Improvement—Institutional and Governmental Aspects*; and (3) *Control of Environment—Economic and Technological Prospects*.

This afternoon we deal with future aspects of environmental improvement. Looking ahead, perhaps for the remainder of this 20th century, it would seem that three major programs will play major roles in improving our environment (air, water, and soil). These are *research, resources planning and development, and pollution control activities*.

Bold new legislation and dynamic new programs have been passed by the Congress and approved by President Johnson in the past 2 years. These include more than 40 important conservation bills covering water and air pollution control, water resources research, water resources planning, solid waste disposal, Land and Water Conservation Fund, Highway Beautification Act, Wilderness Act, Federal Water Project Recreation Act, and many others.

These emphasize the three-pronged attack of research, planning and development, and quality control. These three together com-

³ Director, Office of Water Resources Research, Department of the Interior.

prise a sound approach to improving the quality of our environment. Our resource economists say that an adequate supply of essential natural resources is assured for the foreseeable future. Consequently, it is right and proper that our major concern has shifted from the quantity of raw materials to the quality of our natural surroundings.

SPEAKER: S. Dillon Ripley

The emphasis on environmental improvement, as an open admission of unfavorable interrelationships between man and his natural resources, represents the most significant advancement to date in the evolution of human society. The cause for the imbalance is clear—the environment needs improvement because there are too many people for the finite resources of the earth. The future of environmental improvement depends largely on the level at which we harmonize our population with our environment. Even at our current level the need for environmental improvement is so urgent that motivating challenges in science and technology, education, behavioral sciences, and the humanities—indeed, all areas of human endeavor—will continue indefinitely into the future. It may be necessary to consider reducing the population below its present level to create favorable environmental relationships essential to man's survival as a species.

Our success in adjusting human populations to the resources that support them depends largely on our conceptual interpretation of the world in which we live. To gain perspective let's step off the earth for a moment and look at it from outer space. As we orbit the globe, studying it in depth with instruments and computers that leave no technological problems, we develop a concept of the earth as a series of highly complex open-energy systems powered by solar radiation. Through the photosynthetic process in the green mantle of vegetation solar energy is incorporated into organic compounds. Each chloroplast, each cell, each plant is itself an open-energy system, requiring a constant input of energy to sustain it as a living system. Since the energy captured is more than sufficient to maintain the green mantle, the net productivity is available to other organisms, primarily animals. As the energy circulates within the plant, from plant to animal, from animal to animal, and finally through decomposing organisms such as fungi and bacteria, the original potential energy is degraded from con-

centrated form to greater and greater dispersion as unavailable heat energy, until finally all of it is lost to the living systems. One can compare this process of energy flow to an open reservoir with a stream entering at one end and water flowing out over a dam after a period of time in the lake. Maintaining the reservoir requires a constant input of water, which is eventually lost to the system. If the level of the lake fluctuates within relatively narrow limits the system is said to be in steady state or homeostasis.

From our solar platform we quickly grasp the idea that the systems we are looking at have many physical and living components (including human populations), the interrelationships of which are so complex that the components cannot be studied in isolation if we are to understand the structure and function of the system as a whole. The green mantle of vegetation, for example, would be so altered by the sudden elimination of all animals, or even just the pollinating insects, that it would bear little resemblance to its present form. We soon realize that the extremely complex, integrated systems—of which we ourselves are a component—are not only more complicated than we think they are but more complex than we *can* think. These natural weblike systems of living and nonliving components are called "ecosystems."

"Environment" is a magic word these days. Our new awareness of the environment grew in large part out of alarm over the consequences of radioactive fallout and persistent biocides. We have extended our thinking to all problems of pollution of air, water, and soil. "Restoring the Quality of Our Environment" and other documents referred to by Senator Muskie emphasize the environment in assessing the current situation and laying groundwork for national policy and action. We tend to think of human populations on one side of a coin and the environment (the rest of the ecosystem) on the other side, whereas in reality we are dealing with one and the same coin—with one open-energy system. What I have been leading up to is that we must graduate in our thinking from conceiving the environment as something separate

from the human population, however convenient it may be for impressing the public with the urgency of problems and implementing programs. I do not wish to belittle the significance of the new emphasis on the environment in its present simplified form, for without public support we would accomplish little in the improvement of the ecosystems in which we live. But I do want to stress the significance of viewing the ecosystem as a whole. The future of environmental improvement depends not so much on our technological ingenuity to cope with disposal of wastes as it does with achieving a rational, self-sustaining homeostasis of human populations within the ecosystems of the earth.

The basic problem therefore is to acquire sufficient knowledge about our ecosystems to provide the feedback controls essential to homeostasis. We simply do not know how long man can continue to degrade the world's open-energy systems without destroying the human part of the system. Under the present circumstances the only sound approach is to turn off the population valve, assess the damage to our natural resources, strive to restore the quality of our ecosystems, and engage in a vigorous program of research and education to provide the knowledge required for the evolution of human societies of high quality. As John Middleton stated, we must relate our populations to our resources—not our resources to our population.

The foundations for improvement of human ecosystems lie in the biological and cultural evolution of man. Like other biological organisms man is endowed with genetic information through which he is morphologically, physiologically, and behaviorally adapted to the complex weblike energy system of which he himself is a component. Unlike other organism's, man's intelligence is so highly evolved that he is not restricted to a narrow pattern of ecological behavior. In terms of thermoregulation, for example, man is strictly a tropical animal, but through technological ability he can survive anywhere on earth, including the depths of the ocean. The capability of living in a spaceship 100 miles above

the earth gives us an extraordinary sense of ecological superiority. The realities of our physiological limitations are nowadays conceived in the alarm over the effects of radioactive fallout on hereditary material and the health hazards of chlorinated hydrocarbons. We are also acutely aware of our biological evolution when we recognize that a primitive annual birth rate of 45 per 1,000 was essential to balance a death rate of the same magnitude a million years ago. The consequences of reducing death rates to less than 10 per 1,000 without an equivalent reduction in birth rate are now apparent in our exploding populations.

With respect to his cultural evolution man is like an invading species encountering little competition in a favorable new ecosystem. The ecology of invasions usually involves geometric growth in population, overshooting the capacity of the new system to support the exploding population, and eventually the achievement of population regulation in a modified ecosystem. In his book, *Limits of the Earth*, Fairfield Osborn documents his thesis that the great periods of history are intimately identified with favorable relationships of man to his natural resources and that apparently indestructible empires dissolved when the land lost its productivity. We have now reached the limits of the earth and we are faced with the urgent problem of achieving homeostasis in natural energy systems with man as a member. This involves stabilizing, or even reducing the human population of the world, and the rational use of natural resources without altering the ecosystem beyond the capacity of the human organism to live in it. Hopefully, our deep concern over environmental improvement represents the signal in a cybernetic system to set into motion the negative feedback essential to bringing our populations into steady state within humanized ecosystems.

The scientific community is rising to the challenge of this overriding world problem through the International Biological Program (IBP), the central theme of which is to broaden the productivity base for human populations. The IBP represents an un-

precedented opportunity to seek a deeper understanding of the functioning of human ecosystems, to assess man's impact on natural systems, to establish ecological baselines for measuring further impacts, to study the bioenergetics of natural systems, to investigate human adaptability, and to provide the foundations for a program of research and education to assure the continued existence of the sort of man that we know.

Although the IBP program is to run for 7 years, beginning in 1967, it must be considered as the impetus for a lasting effort to understand human ecosystems, rather than a program that will solve our problems of imbalance. The future of environmental improvement can be enhanced by an effective IBP, and I would therefore urge strong support of the program by scientists, the Federal Government, private foundations, and the general public. Achievement of steady states in man's ecosystems before irreversible damage occurs may well depend on our accomplishments during the IBP. I call for support of the IPB because it is evident during the present planning stage that we are not giving it the full attention and funds required to accomplish the objective so vital to us all.

The problems of steady states in human ecosystems are urgent and formidable, requiring the concerted effort of academia, governments, industry, and the general public. On the academic front, the land-grant universities now have opportunity to play another significant role in the development of our country. The talent at these universities since the enactment of the Morrill Act in 1862 solved the problems of food, at least for the United States at our current population level, so effectively that they are now amply free to assume a significant role as schools of natural resources where holistic approaches can be taken in contributing through research, education, and extension to the achievement of harmonious adjustments between human populations and their resources. Opportunity for developing the foundations for a new role of the agricultural colleges lies in the Commission on Educa-

tion in Agriculture and Natural Resources (CEANR) which is financed by the National Science Foundation through the National Academy of Sciences-National Research Council. CEANR can be one of the cornerstones in the foundation of an effective national program in ecosystem science. Here is a timely opportunity to recast the agricultural schools with a purpose more fundamental than that for which they were created. If this challenging new role is accepted, success will depend on curricula soundly based in mathematics, chemistry and physics, biology, and the social sciences and humanities. The first 2 years, at least, of the new agricultural colleges will resemble those of the top liberal arts colleges in the country. Members of CEANR are working jointly with CUEBS (Commission on Undergraduate Education in the Biological Sciences) on the design of fundamental curricula in the natural sciences that can become solid bases for education in ecosystem science.

As we emerge into this new era of ecosystem ecology, the shortage of well-trained ecologists is so critical that every effort must be made to reduce to a minimum the time lag in producing an adequate flow of university graduates. Special summer institutes for university professors, traveling lecture teams of leading ecologists, interchanges of students and professors between universities, and more emphasis on biological field stations are required to speed up the educational process. The future of environmental improvement depends greatly on our success in preparing scientists to study and to manipulate human ecosystems.

The flow of sound information through society will play a significant role in the future of environmental improvement. All too frequently ivory-towered scientists have been silent in transmitting ideas and data essential to the general public in helping democratic governments arrive promptly at sound decisions. The impact of such communicators of knowledge as Rachel Carson and Ralph Nader illustrates the public thirst for knowledge of concern to society. Research on information flow is urgently

needed to speed up the diffusion of knowledge and development of action programs in ecosystem improvement. The Ecological Society of America, as the leading organization of professional ecologists, can play a vital role in promoting information flow and guiding national policy during the critical years ahead.

The future of environmental improvement depends most of all on our willingness to undertake the task. We have been eminently successful in improving public health throughout the world—thereby reducing death rates and inadvertently threatening our own future with overpopulation—because we had the motivation and drive to undertake a task of direct concern to our personal welfare. To accomplish the Herculean task ahead in ecosystem improvement requires a motivation equal to that of our desire to improve health, reduce death rates, and increase longevity. Such motivation requires an overpowering objective such that we are willing to channel our human resources, wealth, and energies in directions that show promise of achieving our goals. As Sir Julian Huxley has pointed out, our ultimate aim should be to increase the richness of life and enhance its quality. To quote Huxley:

“Fulfillment” is probably the embracing word; more fulfillment and less frustration for more human beings. We want more varied and fuller achievement in human societies, as against drabness and shrinkage. We want more variety as against monotony. We want more enjoyment and less suffering. We want more beauty and less ugliness. We want more adventure and disciplined freedom, as against routine and slavishness. We want more knowledge, more interest, more wonder, as against ignorance and apathy.

To create a world in which spiritual, esthetic, intellectual, and emotional content at the levels of maturity Huxley and others envision provides a challenge far greater than that of landing a man on the moon. We already have sufficient knowledge of “natural” ecosystems (those with a minimum of human influence) to place confidence in the principle that the most homeostatic systems are

those with the greatest diversity in species composition and interactions of the systems components. Man's fulfillment, it seems, will depend on creating humanized ecosystems of maximum diversity. This is a world problem, and as I indicated earlier, motivating challenges focused on this theme will continue beyond the foreseeable future. I mention this not only to inspire the intellectuals, landscape architects, scientists, and political leaders, but to dispel any fears on the part of economists and industrialists who visualize stagnation in gross national product as a consequence of stabilizing human populations. I am suggesting that we divert our growth to quality rather than quantity of human beings. Our evolving human societies must adapt to their local and regional ecosystems. As a biological organism man's intelligence is his most outstanding adaptation for survival. Application of intelligence to understanding the functioning of the earth's open-energy systems and the directing of cultural evolution toward diversified, mature, humanized systems in which man can achieve fulfillment is urgently needed at this point in time.

Time is of the essence. We cannot stabilize our population overnight and then concentrate on environmental improvement. The momentum of population increase is such that we are faced with ever-increasing problems of pollution of air, water, and soil during the period in which we are striving for control. We need the best of mathematical modeling and computer simulation to predict environmental changes and provide the basis for the development of technology to achieve acceptable tolerances of pollution. However, leaving aside the technological problems for the moment, one of the most effective ways of reducing time lags in motivating the public toward environmental improvement and designing the kind of world in which we achieve fulfillment (and reach for more) is to develop international centers for advanced studies. Here the best minds in science, technology, and the arts can interact in a unified effort to create ideas and to provide guidance in research and education in the achievement of harmonious

environmental relationships and the evolution of societies with ever-expanding fulfillment. Through our activities at our own Center for Advanced Studies, and through our newly formed Office of Ecology, the Smithsonian Institution will focus attention on the critical problems of man's ecological behavior.

In summary let me reiterate that the future of environmental improvement depends basically on achieving a rational degree of homeostasis in mature, humanized ecosystems. The immediate task is to stabilize the world population at or below the current level by bringing it down from the heights to which our momentum will inevitably carry us. Unless we are successful in this task, all efforts in environmental improvement will be absorbed by increasing populations, our ecosystems will degrade, and we will not achieve the steady state essential to our survival with fulfillment. Much will depend upon our concept of the world and our ability to motivate society to become as concerned about environmental improvement as it is about public health. The task is so great that I can see no limits to economic or social growth in the process of limiting our population and striving for maturity. Environmental improvement, or better still the improvement of human ecosystems throughout the world, provides man with the greatest challenge he has ever faced. Hopefully this challenge will provide the motivating force for international cooperation that will lead to a peaceful, highly diversified, and interesting world in which the intellect and creativity of man can continue to evolve.

REACTION: Joseph L. Fisher

Without a doubt, in this country at least, there has recently been an acceleration of interest in problems of the natural environment, a widening and deepening concern for "pollution and all that." This has resulted from the rapid population growth during the two post-war decades, increasing urbanization and especially suburbanization with its sprawl out over the rural landscape, and the desire for clean water, air, and landscape for outdoor recreation and scenic amenity. The response to the growing awareness of environmental problems has been typically American: a spate of books and popular articles playing upon fears and proclaiming imminent calamity, an intensification of legislative and administrative action at the several levels of government including several freshets of Federal money poured into State, local, and university budgets, and a notable ferment on the intellectual front making use of the newer techniques of systems analysis. S. Dillon Ripley's paper reflects quite a bit of all of this, but chiefly it aims to place our present emphasis on environmental improvement in the perspective of ecology.

In my few reactions I shall merely try to add a little to Dr. Ripley's excellent presentation and perhaps adjust the focus here and there. But with his main thesis—"man's fulfillment will depend on creating humanized ecosystems of maximum diversity"—I have no quarrel. It is a lofty aim and one which commands and must receive our earnest attention.

My principal addition or refocussing (I am not sure which it is) is to upgrade somewhat the importance of technology, social institutions, and human and cultural elements generally as compared to the "natural" and ecological factors. Granted that the earth, or significant portions of it, may be regarded as open-ended energy systems aiming toward a stable state, it does seem to me that the level and character of the so-called stable state will depend greatly on the technological and other cultural apparatus

that is utilized. The "limits of the earth" are probably much farther out than are implied in this paper. Harrison Brown in various writings, especially *The Challenge of Man's Future*, has speculated that 50 billion persons may be about as far out as we can go; while others seem to think that we have already passed the outer sustainable limits of the earth's carrying capacity. Dr. Ripley says, "We have now reached the limits of the earth . . ." and ". . . the environment needs improvement because there are too many people for the finite resources of the earth." The assertion requires proof.

My own view is that the earth can probably stand quite a few more people so far as its natural resources are concerned. Since the Second World War in the more developed countries of the world per capita economic growth on the whole has been quite satisfactory, and there is nothing in prospect for the next few decades that convinces me that such economic gains will stop or even slow down. In the heavily populated and less developed countries, which admittedly contain two-thirds of the world's population, the picture is not nearly so favorable. But even there the best statistical information that can be put together indicates a slow improvement in per capita food consumption and a much greater increase in per capita energy consumption. Looking farther into the future—a century, say, or more—there are vast unknowns as to the order of the population-resources equation and especially regarding the cultural-institutional factor.

The critical factor, it seems to me, is not to be found on the natural resource side, or even on the population side, looking ahead over the balance of this century, but rather on the human and institutional side. Will people, enterprises, and governments be able to develop their agriculture, industries, and services so as to feed and otherwise supply the growing number of people at rising levels of living? Will programs of family planning and population limitations really take hold where they are most needed and during the next decade or two so as to reduce the incessant pressure of

more and more people, particularly nonproductive youngsters, and offset the rapid reductions in the death rate? The world needs a double emphasis on fertility: increased fertility of the soil and decreased fertility of human beings.

But the main thrust of this conference and of Dr. Ripley's paper is not on the quantitative side; it is on the qualitative side and concerns the improvement of the natural environment regardless of how the numbers game comes out. The evidence that we are messing up our natural environment according to esthetic and ecological standards, or compared to what we might do if we put our minds to it, is overwhelming. This is not to say that things are necessarily worse than they used to be in this regard; despite the hue and cry about water pollution today in this country, hardly anyone dies of typhoid, whereas a century ago typhoid was common. Insecticides have virtually rid this country of malaria and have made great inroads on this debilitating disease in most other parts of the world. But the facts cannot be gainsaid: in the matter of our handling of the natural environment we are doing much worse than we know how to do. Fortunately what Dr. Ripley calls a "negative feedback" seems already to be at work here in this country. The very awareness of environmental damage has set in motion a legislative (Senator Muskie) reaction, an administrative (Secretary Udall) reaction, an educational (League of Women Voters) reaction, and an institutional (Delaware River Valley Commission) reaction. And many other similar examples could be cited. Not the least is the reaction which has been sweeping through the scientific and educational communities of which the International Biological Program and the Commission on Education and Agriculture and Natural Resources mentioned by Dr. Ripley are splendid examples.

I like Dr. Ripley's call for international centers for advanced studies such as that in his own Smithsonian Institution, with its Office of Ecology which has exciting possibilities. Along this line I have argued recently for a World Institute for Resource Analysis

in which a number of leading scholars and practitioners would be gathered with the primary responsibility for developing improved techniques for analyzing resource and related problems and applying them in demonstration situations. Such an institute might be attached to the United Nations or one of its cooperating agencies, or it might be organized through the Academies of Science in the various countries. Possibly the Smithsonian Institution could play a leading role.

To return finally to what I regard as the main thrust of Dr. Ripley's paper—"achieving a rational degree of homeostasis in mature, humanized, ecosystems"—I wish there were a more dynamic element somehow built in. I have some concern lest the ecologist's delight in the well-balanced, smoothly functioning steady state ecosystem of the pond be projected uncritically to the earth and its human population. In the latter case the variables are tremendously greater in number and complexity of interrelations, and the variety of acceptable conditions or states is very large indeed. The number of basic building blocks and subsystems that can be arranged and rearranged, and worked with, seems almost endless. Furthermore, depending upon one's philosophy, are the creative human elements which open wide the range of possibilities.

For example, it does lie within our reach to establish rather good standards of water purity in our rivers if we will but apply our knowledge, investment funds, and institutional capacity to the task. Nor is it beyond our reach over the coming few decades to establish programs of family planning through which population itself will be brought within the ambit of conscious regulation. Of course these things won't happen automatically; they will require research and study, leadership, educational effort, and a general will to action.

Dr. Ripley says "man's fulfillment will depend on creating humanized ecosystems of maximum diversity." Man's creative role in his own fulfillment must not be underrated; to play the role

honorably and to the full gives man both purpose and dignity. While developing his economy he must understand and live with the constraints of his ecology. While striving to master his environment he must obey its imperatives. Fortunately nature leaves man much scope.

To borrow and by implication extend the words in the last paragraph of Darwin's *Origin of Species*, "There is a grandeur in this view. . . ." There is a special grandeur in the idea that man and his social institutions can be decisive in the outcome of the grand ecological issue of population and resources.

REACTION: Ian L. McHarg

From constant repetition, we have accepted the prospect of 300 million Americans living mainly in the great wens of megalopolises covering one-tenth of the land area of the United States. We have accepted, as the mode of growth, the extension of the status quo, accretion of more hotdog stands, diners, gas stations, auto cemeteries, ranchers, split levels, sagging wires, billboards, concrete and asphalt—adding annular rings to existing centers until they coalesce. We have the solemn assurance of Dr. W. C. C. Wheaton that slums are increasing faster than they are being replaced. We have the assurance of the distinguished epidemiologist, Dr. A. M. M. Payne, that cancer, heart disease, kidney disease, neurosis and psychosis are urban epidemics. Finally, there is the evidence of the Midtown Manhattan Study by Cornell Medical School that 20 percent of the sample population were indistinguishable from patients in mental hospitals. Yet this metropolis may increase from 12 million to 30 million people in the next 30 years.

New York suffered a serious drought last summer; in the preceding spring serious floods ravaged the Northwest and Southwest; smog, forest fires and mudslides have become a way of life in Los Angeles, while the San Andreas fault rises in temperature in San Francisco. Philadelphia is menaced by the intrusion of salt water in the Delaware, and Lake Erie is almost septic. Atmospheric pollution and water pollution are now endemic urban conditions.

Is this the face of the land of the free, the home of the brave?

Paradoxes proliferate—private wealth and public squalor, a preoccupation with ephemeral consumer goods and disdain for the physical environment. There is an almost pathological concern for personal cleanliness and cosmetics paralleled by abysmal public standards for environment, air, and water. Medical services for the individual set high standards while public concern for the environmental contribution to pathology is minimal. Interest in

music, painting, and sculpture increases; public standards for architecture, landscape architecture, and civic design remain rudimentary. As a final paradox, the most modern, expensive and sophisticated apartment house in New York dumps raw sewage directly into the East River.

Where does planning stand as it confronts this anarchy, despoliation and disinterest?

The insights of landscape architects and architects have been enlarged by the perceptions of the social science planner, but this spectrum remains incomplete. The world, the city and man as responsive to physical and biological processes—in a word to ecology—are entirely absent from the operative body of planning knowledge. If the planner is part social scientist, part physical planner, he is in no part natural scientist nor ecologist. Yet, I submit, no single body of knowledge has greater relevance to the problems confronted by society, and thus, by the planner, than does ecology.

The ecological view has a greater detachment than do the planning professions and the social sciences. It also brings quite distinct and generally unfamiliar judgments to bear. This might well be demonstrated by two brief tales:

Ecology is the study of organisms and the environment. Organisms are united as members of the biosphere, the thin layer of life covering the earth. Loren Eiseley has told the parable of the biosphere which, paraphrased, reads, "Man in space is empowered to see the earth, a rotating sphere; he sees it to be green, green from the verdure on land, the algae in the sea, a green celestial fruit. Upon this celestial fruit he sees blemishes, gray, brown, black, from which extend dynamic tentacles. He perceives them to be the works of man and asks, 'Is man but a planetary disease?'"

The biosphere can be considered as a complex of interacting organisms, including man, responsive to the laws of dynamic equilibrium. There is a necessary numerical relationship between

plants and herbivores, herbivores and carnivores, carnivores and man. This is true for the microscale as for the world. The distance between producer and consumer may increase, but the relationship is inexorable. There are environmental requirements for life, growth and health which are equally demanding.

A second parable, my own, suggests equally strong evidence for a concept of dynamic equilibrium and the need for a planning process based upon ecological understanding.

The atomic cataclysm has occurred. All life is extinguished save in one leaden silt where, long inured to radiation, persists a small colony of algae. They perceive that life exists in them alone and that 2 billion years of evolution must proceed from them alone to return to yesterday. They come to a single, spontaneous, unanimous conclusion. Next time, no brains.

The threat to equilibrium may come from starvation, asphyxiation, poison, exposure, assault, radiation, disease, age, natural catastrophe or any combination of these. The individual organism is threatened with these as is society. He has levels of tolerance within which lie health; across this threshold lies pathology and death. And so for society.

From the foregoing we can accept the concept of an interacting biosphere which, in plants, animals, and, at the involuntary level, in man, aspires towards dynamic equilibrium. This should hold for human, rational processes, particularly in planning.

What conditions attend dynamic equilibrium? It will tend not to oscillate between extremes. The human body temperature, in health, remains at 98.6° F. The stream in equilibrium tends not to oscillate between flood and drought. The growth rate will tend to be stable. In man, inordinate cell production is associated with cancer; drosophilae in a jar breed to extinction. In ecosystems equilibrium is associated with large number of species. Disequilibrium is identified with monocultures. Complexity is a measure of equilibrium, simplicity of disequilibrium and vulnerability. Finally, conservation of energy, its utilization and recycling through

the system, is likely to attend systems in equilibrium.

How can the ecological view of dynamic equilibrium be applied to the planning process? There are certain fundamental requirements: that knowledge of the natural sciences be invoked to explain physical and biological evolution; that this same source provide the best current explanation of natural processes, limiting factors in such processes, criteria of stability and instability, evolution and retrogression. Such an explanation will provide the program for choice. It will reveal relative values among resources, intrinsic prohibitions and permissiveness—in short, the program for planning, which is to say, conscious action related to human goals.

An ecological planning method at a regional scale would contain certain identifiable components:

1. Ecological inventory.

An analysis of geological evolution, climate, the water regimen, physiography, soils, plants and animals *as process*—“the given form.”

2. Historical inventory.

An analysis of human adaptations over time reflected in changes to the natural environment and the inventory of physical plant, *as process*—“the made form.”

3. A description of natural process.

This includes hydrosphere, lithosphere, atmosphere and biosphere; forest and marsh, lake and stream, mountains, flood plains and farmland, surface and ground water—as process.

4. A description of limiting factors.

These will vary from place to place. They may include ground water resources, dependable low flow, frost-free days, high productivity soils, land suitable for urbanization, fog-free sites, etc., etc.

5. Attribution of relative values.

- (a) To existing resources.

- (b) To latent or prospective resources.

What roles and values natural processes have and thus affect the lands they occupy—the role of forests in the water regimen, climate and micro-climate, wildlife management; the roles of farmland, marshes, streams, mountains, oceans, values of mineral resources, areas of scenic, historic, ecological importance, transportation corridors, etc., etc.

6. Description of intrinsic permissiveness and prohibitions to prospective land uses.

Intrinsically, productive soils are eminently suited for intensive farming; other soils are less so suited. Minerals only exist where they exist. Steep slopes are generally unsuited to urbanization; shallow slopes and flat lands are better suited. Marshes are valuable for wildfowl and for aquifer recharge, but generally unsuitable for settlement. Beaches are tolerant; dunes intolerant. The land itself reveals inherent opportunities, permissiveness and prohibitions. These are values and contain implications for preservation and prospective land uses.

Given this information, it becomes evident that each area of land is likely to perform several roles. It is also evident that certain roles are compatible, others incompatible. Thus one area may be simultaneously planned and managed for forestry, wildlife, recreation; for flood, drought, erosion and climate control. Another site might be managed for open quarrying, land reclamation followed by recreation and settlement. In this case certain land uses are incompatible simultaneously, but compatible and complementary in time sequence. In another case poor agricultural land may be managed for farming, retired into forestry, wildlife, recreation and ultimately for settlement.

For this type of examination certain major resources can be identified and fundamental natural processes will be seen as linked. Thus upland forest and estuarine marsh may be performing identical roles in the water regimen. This being so, ecological perception suggests multiple-use planning and management responding

to natural process, and the intrinsic values, permissiveness and prohibitions therein contained.

When the ecological view is brought to bear upon the city, its power diminishes as it approaches the center. It remains powerful for metropolitan problems, for such natural processes as persist in the city, and for the interpretation of air and water processes, yet it cannot describe the city as an ecosystem. Nonetheless there remain valuable and provocative ecological insights which promise new perceptions for understanding and resolving urban problems.

Evolution proceeds from unicellular organism to multicellular organism; one species, many species, from simplicity toward complexity. Evolution is towards complexity, retrogression towards simplicity. Multiply simplicities and uniformities result; multiply complexities and diversities result. As greater numbers of species occupy an environment, they utilize more and more pathways; as a result, opportunities for new habitats and environmental resources diminish. Stability is a product of such complexity. Instability accompanies simplicity. In multispecies ecosystems materials are cycled and recycled; order is high, wastes few—which is to say, entropy is low. In summary, one can associate two opposite sets of descriptive terms, each group having an internal consonance: the first includes simplicity, uniformity, instability, and high entropy; the second includes complexity, diversity, stability, and low entropy. We can measure evolution as from simple and its corollaries towards complex; and retrogression as from complex and its corollaries towards simplicity.

If large populations of few species are indicators of ill health, what can one say of central urban habitation where preponderant populations are men, lice, rats, pigeons, and starlings? If simplicity is evidence of an early stage in evolution, what can one say of subdivisions, housing developments, the redevelopment of central business districts? If simplification is evidence of retrogression, what then of zoning, a method of ensuring simplicity? If diversity is an objective, what can one say of a process which takes diverse

and complex natural environments and reduces these to conformities and simplicities?

These questions suggest that the ecological view and the criteria of ecology have relevance to the problems of man and community. If the laws are true for plant and animal communities, it is unlikely that they will be suspended for cities and for men.

